METALLURGIA

THE BRITISH JOURNAL OF METALS.

FEBRUARY, 1931. VOL. III. NO. 16.

The British Industries Fair

Metallurgical Developments at Birmingham.

Model of Fifteenth-century Galleon, constructed almost entirely of Nickel. Exhibited by the Mond Nickel Co., Ltd.

THE success of the national effort to display the resources of British industry is indicated by the continued expansion of both sections of the British Industries Fair. Not only is floor area occupied by exhibits greater this year, but the scope of the Fair is increasing. Although not yet fully representative, it has been augmented by the Cotton Textile Section at the White City, and, during the first week, a further addition to its scope is a display of artificial-silk goods at the Royal Albert Hall. This Fair is recognised to be by far the greatest display of entirely national manufactures held in any part of the world. It is an effort to bring about more effective selling of products, with a view to restoring normal production and consumption. Its complete success would gradually improve the present industrial slump, and prices would become more stable, profits restored, and one of the country's most disturbing problems—the unemployed—would gradually solve itself.

The world-wide depression has caused prices to fall, with the result that industry as a whole has concentrated on economy and efficiency. Reconstruction and rationalisation schemes have been adopted, in many cases, to cut out obsolete or redundant plant, and to centralise the productive organisation. In spite of many disturbing factors there are signs that these steps have been successful, and a slight improvement is manifest which seems to indicate that the worst phases of the depression are over. Now that many basic industries have improved through adversity, and are in a better position to meet competition, a successful result of the Fair will undoubtedly show substantial progress before the end of the year.

Modern industrial conditions demand the utilisation of, every available means that facilitates progress, and every advantage must be taken of improvements and developments that cheapen, as well as improve, the quality of materials. The most modern machinery must be installed, and the latest technique employed to achieve this end. Old machinery should be ruthlessly discarded, old methods relegated to the past, and plants completely reconditioned and modified to meet the exigencies of the present and immediate future. This should be borne in mind when visiting the Fair, which exhibits the progress made in a wide and increasing range of manufactures, which will maintain for this country that honoured reputation established long ago.

The lighter products of British industry are, as usual, exhibited at the London Section, and among the features of metallurgical interest are the sections devoted to cutlery and scientific and optical instruments. The Birmingham Section, which covers a floor area of over eleven acres, displays the products of the heavier industries, and it is in this section that developments in materials, processes, plant, and equipment have a more definite metallurgical aspect. Visitors to both sections of the Fair will be able to see the exhibits which demonstrate so effectually the development of industrial enterprise, the skill and craftsmanship involved in the wide variety of products, and will, in a measure, be able to grasp the significance of British resources and possibilities.

In the metallurgical section the continued development and improvement in the standard of manufacture of iron and steel, as well as non-ferrous materials, has introduced new applications. This has involved new designs for finished products, and improvements in, or the development of, new tools and equipment to meet the special needs of each product, and to facilitate the production of each article. The exhibits indicate development and superior technique in production from the crude pig or ingot through the various processes of manufacture to the assembled and finished article. Even pig iron, formerly regarded as crude pig, has come to be known as refined pig iron, a wide variety of brands and grades being on view.

Among the noteworthy exhibits of this kind are the special low-sulphur and low-phosphorus pig irons produced at Workington. The hematite ores of this district are very pure, and eminently suitable for the manufacture of high-grade steels. A special brand of refined pig iron is also exhibited which is suitable for high-quality castings, such as Diesel engine cylinders and other castings subjected to

heavy wear and high stresses : an all-mine brand of refined pig iron for whiteheart malleable castings, and another for blackheart malleable castings. It is worthy of note that these all-mine refined pig irons of the United Steel Co. are sold only to analysis, and a complete analysis is supplied with each consignment. Other interesting pig irons exhibited include the cold-blast iron of the Eldrow Brand.

Wrought Iron and Mild Steel.

A considerable number of exhibits display the particular uses of wrought iron and mild steel. A revival in the proportionate demand for wrought iron of high quality is due to its superior resistance to atmospheric corrosion, and it is used when strength to resist sudden stress and unequal loads is required. In wrought iron and mild steels, when

One of the Four New Heat-treatment Furnaces exhibited by Birmingham Electric Furnaces, Ltd.

the extensions cease to be proportional to the loads, it is recognised as the limit of proportionality, which is one of the fundamental factors upon which engineering structures depend. It is generally lower than the numerical value of the yield joint ; it is interesting, therefore, to note that N. Hingley and Sons are exhibiting a wrought iron having an ultimate strength of 21 tons per square inch, which has a higher limit of proportionality than a steel of an ultimate strength of 29 tons per square inch.

The increasing use of pressings make a big demand on mild steel. For simple work of this kind it is possible to use ordinary mild steel in the cold-rolled close-annealed condition, but for work requiring to be deeply drawn, or very sharply bent, it is necessary to use a special deep-stamping steel, in order to obtain regular results. A special low-carbon dead-soft steel, intended for the bulk production of pressings, has been produced by British Rolling Mills, Ltd., and known as Brymill B.R.M. 2 brand. This steel is made to close limits of analysis, but further than this, the subsequent operations are carefully controlled by the laboratory, and uniformity is guaranteed. There are, however, a few jobs where such a steel, even as the one just described, is not sufficiently ductile, or it may be that it is desired to omit certain intermediate operations or annealings—a growing tendency to reduce production costs. For such work extra-special deep-stamping steel is designed. This is claimed to contain a minimum content of 99·6% iron, and is as soft as steel can be made. Particular care is taken to see that the material is free from segregation, piping, lamination, etc., and production control exercises a rigid influence. This is a recent introduction which has already proved itself capable of solving some difficult problems.

The use of steel furniture, in both offices and works, is increasing as its advantages are being realised, and its absorption of mild steel is considerable. Some examples of this class of work are exhibited by Messrs. G. A. Harvey and Co. (London), Ltd., who have made an extensive addition to their works to cope with increasing demands. Of outstanding interest in connection with this exhibit is the extensive range of perforated metals and their wide range of applications. A very comprehensive assembly of wrought-iron and mild-steel components is exhibited by Stewarts and Lloyds, Ltd., special attention being directed to sheathed steel tubes for use with unusually corrosive water, and to their screwed and coupled tubes of genuine puddled wrought iron made to the specification of the Institute of Gas Engineers. Other exhibits of interest are this firm's tubular-steel pit props, which, as a result of added security, increase output and reduce costs in normal mines.

Cold-drawn steel channels, tubular sections, and pressings are apparently unlimited in variety : the utility of these forms of semi-finished material is increasingly realised, and new forms to suit particular types of construction are continually being devised and produced. Improvements in tubular processes have produced thousands of different articles, and many interesting developments in tube construction exhibited in metal furnishing, chairs, settees, tables, showcases, racks, hospital fitments, dinner wagons, as well as structures for the transport of goods give some idea of the developments made in this work. Visitors should inspect the exhibits of the Britannia Tube Co., Ltd., Accles and Pollock, Ltd., and British Tube Mills, Ltd., to obtain some idea of the wide range of applications that have been developed. Special sections of cold-rolled and cold-drawn steels are exhibited by James Mills, Ltd. This firm specialise in standard sizes and sections of bright-drawn steel, which are accurate to size, and ready for cutting up and fitting. Bars up to 25 ft. in length may be obtained, and, in some instances, the sections are accurate to plus or minus 0·0005.

Case-hardening Steels.

The case-hardening steels are finding increasing applications to the desirability of maintaining strength and toughness to resist heavy duty, and yet to maintain an extremely hard-wearing surface. Many exhibits show fractures of their special brands of straight carbon, nickel, and nickel-chrome case-hardening steels, while British Rolling Mills, Ltd., are demonstrating the machining properties of their C.H. 2 free-cutting case-hardening steel. A special component is being produced at the exhibition, and thus visitors will have evidence of the quality of the steel which has been improved considerably since the last B.I.F. The machining qualities, as well as mechanical properties, are now claimed to be equal to any steel of its class.

Average tests on standard $1\frac{1}{8}$-in. diameter samples are as follows :—

Tensile strength	44 tons per square inch.
Elongation on 2 in.	20%
Izod impact	50 ft.-lb.

The specification limits of these steels have been narrowed down and tests rendered more severe, but in uniformity of quality that is desirable. Many case-hardening steels are produced which have been proved, over long periods, to possess special merit. It is recognised that the success of the case-hardening process depends to some extent on the skill displayed in the operation, but the subsequent behaviour of the case steel depends largely on the character and quality of the original steel.

Many case-hardening compounds will be exhibited for the first time. One of these is Brymillite, which is a granular substance, designed to support the work during carburising ; that is, it does not shrink nor yet burst the lids off the pots. Being a repeating agent, and bulky for a given weight, it is economical. It is claimed that a minimum of dust is formed and the steel is left clean, while a case is produced, that gradually merges into the core without a sharp line of demarcation.

Alloy Steels.

Probably in no branch of the alloy-steel industry have greater developments been made than with the stainless

steels. The most noticeable feature in their increased application is in regard to aircraft structures, particularly flying boats. While it is true that complete hulls have not yet been made from stainless steel, yet many fittings and components, as well as planking of the underwater portions of hulls, have been constructed of this non-corrodible material. One of the advantages of stainless steel for this purpose is the fact that it does not depend upon the application of surface coatings for its corrosion-resisting qualities.

Apart from the rapid progress of the nickel-chrome alloys as corrosion resistant steels, remarkable developments have been made in its heat-resistant qualities. Numerous problems affecting the production of stainless steel have been overcome, and the material is now available in many diverse shapes and forms. There is no doubt that the display of this alloy steel will prove to be one of the most outstanding in the metallurgical section. Considerable space is allocated to Firth's Staybrite Steel and polished sheets, and the high finish of cold-rolled strip, produced by this firm, marks a notable advance in technique. A wide range of fittings and equipment show the rapid growth in application of this steel. Another feature of this display is the unique range of castings which demonstrate the value of Staybrite for corrosion-resistant purposes. It is noteworthy that the Britannia Tube Co. are now manufacturing Staybrite steel tubes, and will exhibit some specimens at the Fair.

Another firm that has made a considerable contribution to the advancement of heat- and corrosion-resisting steels, and whose exhibits are confined to this branch of metallurgy, is Messrs. Hadfield's, Ltd. The range of these steels displayed is an important one, and includes Era/H.R., Era/131, Hecla/134, Era/C.R., Galahad and Hecla/A.T.V. The Era/H.R. steels are essentially high nickel-chromium or chromium steels containing, in some cases, small percentages of additional elements, and are particularly suitable for parts subjected to high temperatures where resistance to scaling and "creep" are desired. Progress in furnace construction and general high-temperature engineering is creating a steadily increasing demand for such material, and thousands of tons of these expensive steels have been supplied as both cast and wrought products. To meet the demand for a steel to withstand the conditions now prevalent in high-temperature steam service, where temperatures as high as 1,000° C. are becoming increasingly familiar, the alloy steel Era/131 has been developed. For such conditions, the excellent non-scaling properties of the highly alloyed heat-resisting steels are not required, and such steels are, moreover, often actually unsuitable for working in this particular range of temperature. Another drawback to steels of this type is their somewhat high cost and difficulty of fabrication. Era/131 steel is relatively inexpensive, has excellent mechanical properties within the range of temperature met with in present-day steam practice, and presents little more difficulty in working up than ordinary mild steel.

Nickel-chromium-molybdenum steel. Hecla/134, is developed for the same purpose, but gives higher mechanical tests in the cold. The use of such steels in high-temperature steam work is already fairly common, but unless the composition is well chosen, such steels are liable to dangerous embrittlement after a certain time at working temperatures. The composition of Hecla/134 is the result of an exhaustive research, and its toughness remains unimpaired under working conditions.

The Galahad stainless steels are of the well-known 12/17% chromium type; while the Era/C.R. corrosion-resisting steels are essentially Austenitic nickel-chromium steels, and are particularly suitable for many kinds of chemical plant, domestic ware, and decorative work.

The Hecla/A.T.V. steel is an austenitic nickel-chromium stainless steel, containing a high percentage of nickel, and combining good mechanical properties with resistance to the erosion and corrosion of steam to a greater degree than any other steel or alloy. It is claimed to be perfectly stable at all temperatures met with in steam-turbine work, and is therefore free from the serious disintegration which may occur with certain types of austenitic steels, when working at temperatures between about 500° C. and 900° C. These properties make it an important material for such parts as steam-turbine blades and nozzle plates where severe conditions of erosion and corrosion are to be encountered, and its use in such cases is specified by the British and many foreign Admiralties. It is also largely employed by private users such as power stations and shipping lines. It is interesting to note that in regard to the production of Hecla/A.T.V. and Era/H.R. steels, Messrs. Hadfield's are associated jointly with La Societe Anonyme de Commentry-Fourchambault et Decazeville, and with the well-known Midvale Co., of America.

Many other firms are displaying a variety of grades of stainless steels, suitably graded to widen their range of application.

Among new developments in alloy steels is a special steel known as Tormanc, which the United Steel Co. are showing. It has been developed as suitable for automobile and general engineering purposes, similar to nickel steel, but more easily machined, where the conditions are too severe for the employment of ordinary carbon steels, but considerations of expense will not allow the use of nickel or more costly alloy steels. It has the advantage of forging well, and is particularly suitable for the manufacture of high-tensile nuts and bolts. The following range of properties may be obtained from this brand of steel on a $1\frac{1}{8}$-in. bar.

	Max. Stress Tons Sq. In.	Yield Point Tons Sq. In.	Elongation % on 2 in.	Reduction of Area.	Izod Value Ft. lb.
In the normalised condition.....	40/45	24/30	30/27	60/50	60/40
Oil hardened and tempered.....	42/54	30/40	28/20	65/50	70/30

It is of interest to note that Tormanc has been selected as the light, strong, alloy steel for the mast for Sir Thomas Lipton's racing yacht. The new mast will be 160 ft. high, and will be made from plates welded by the Quasi-arc process, and in view of the new alloy steel used, it is probable that special electrodes, of a composition similar to the steel, will have to be prepared for the purpose. Two masts are being provided, and these will each absorb 4 tons of special steel.

Alloy steels of every description for all classes of work will be exhibited including all specifications in nickel, nickel-chrome, nickel-chrome-molybdenum, chrome, chrome-vanadium, silico-chrome, and silico-manganese steels.

High-speed Steels.

The ordinary carbon tool steels, when hardened, become constitutionally a solid solution, having great hardness, which is slightly reduced or drawn by heating after the hardening operation. In this way the tool can be given first the desired hardness for the particular kind of work it is designed to perform. When the working conditions are severe, much heat is generated which tempers the tool too much; the solid solution of which hardened carbon tool steels consist is thus too susceptible to permit of their use for many modern purposes. As a result of much research, special high-speed steels have been produced by the addition of other elements such as tungsten and cobalt, which have revolutionised the cutting of high-duty metals and alloys. When these steels are hardened, the presence of the additional elements in the solid solution renders them immune from the effects of over-heating.

A new cobalt high-speed steel is exhibited by Peter Stubs, Ltd., which is claimed to be a super steel. A bar of this steel used as a turning tool has been tested at the Sheffield Testing Works, Ltd., and in comparison with a

standard 18% tungsten high-speed steel, it shows a value of 190·7% superior to the standard.

Another recent development, which is to be the main feature of the exhibit of Arthur Balfour and Co., Ltd., refers to some tools tipped with this firm's "Ultra Capital" high-speed steel. This steel is claimed to be genuine crucible-melted steel, and to be the latest result of metallurgical research. These tools have been placed on the market with the idea of placing in the hands of even the smallest user, without the facilities for treating high-speed steel, a super grade of cutting alloy perfectly hardened and capable of achieving the maximum results that can be expected from genuine high-speed steel. A different type of high-speed cutting alloy, Stellite, which is being increasingly used for tipped tools, tool bits, milling cutters, centreless grinder work rests, etc., is exhibited, and demonstrations of its application to wearing surfaces are given.

Non-ferrous Metals and Alloys.

One of the most interesting displays is that given by the Mond Nickel Co., Ltd. In this instance the exhibits are divided to show a method by which nickel is extracted from its ore, the properties of nickel and its alloys, and many applications of this metal and its alloys. Applications are represented by various nickel-alloy components used in the automobile and marine industries. These consist of nickel-alloy steel gears, a nickel cast-iron cylinder block, a connecting rod of nickel-aluminium alloy, valves of nickel - chromium heat-resisting steel, etc., and among the marine exhibits, turbine blading of nickel-chromium corrosion-resisting steel, nickel-copper condenser tubing, a Monel-metal pump impeller, cabin fittings in Silveroid, and kitchen utensils of copper-coated nickel.

A New Sand-conditioning Machine of the Portable Type by Pneulec, Ltd.

Another interesting exhibit is a model of a fifteenth-century galleon, an illustration of which is shown on a previous page. This is made entirely of pure nickel, with the exception of the nickel-silver base and the enamelled flags, which are of copper-nickel. This ship was designed to show nickel in as many forms as possible, and includes sheet metal cut out and embossed for the sails, rods for the masts, and wire for the ropes; the figure-head is a nickel casting, and the blades of the oars are beaten out from the rod. The whole is constructed on the same lines as a wooden ship, including keel, ribs, and planking, the rivets all being of nickel.

A very wide range of semi-manufactured non-ferrous products are exhibited, embracing ingots in aluminium alloys, brass, gunmetal, and phosphor-bronze, to A.I.D., Admiralty and B.E.S.A. Specifications, as shown by T. J. Priestman; extruded bars in brass, bronze, copper, and numerous other Delta alloys by the Delta Metal Co., who are also exhibiting hot stampings and pressings; copper and aluminium wires, sheets and strips by the British Insulated Cables, Ltd., and many others. The development of stainless steels is making them a serious competitor of the non-ferrous alloys, but improvement in the technique of production is influencing the further development of these alloys, particularly the light alloys, and those that are suitable for drop-forging. Among the non-ferrous forgings displayed are included those of Monel metal, duralumin-magnesium alloys for automobile and aircraft parts, as well as other numerous applications.

Heat-treatment Furnaces.

Many ferrous and non-ferrous alloys depend upon some form of heat-treatment to produce the properties for which they have been developed. In order that heat-treatment can be carried out successfully, the question of suitable furnaces is an important one. The regulation of heat in the heat-treatment of materials has concentrated considerable attention on the need for some form of automatic temperature control. In addition to the control of temperature, many furnace exhibits have as outstanding features the control of the atmospheric conditions within the furnace. The greater appreciation of the necessity for scientific accuracy in the hardening of modern high-speed steel tools has caused the Birmingham Electric Furnaces, Ltd., for instance, to design and construct a new range of furnaces to meet these requirements, one of which is exhibited. Ideal conditions are claimed to be provided by a neutral or slightly reducing atmosphere, so that the steel being treated is neither carbonised nor decarbonised. These conditions are produced by admitting semi-burnt gases through a slit extending across the hearth of the door-opening, thus effectively screening the furnace against the entrance of air. This prevents scaling of the work, and at the same time makes it possible to operate the furnace with the door open.

The heating elements are "Globars," which extend from front to back along the two sides of the furnace. This arrangement gives even distribution of heat, the hearth being fully heated without over-heating any of the elements. The hearth (which consists of bonded silicon-carbide) is trough-shaped, thus preventing the charge from damaging the heating elements, and the vestibule is so designed that the hearth can be moved and replaced without disturbing any portion of the brickwork. The furnace exhibited has a maximum rating of 20 k.w., the hearth size being 12 in. long by 8 in. wide, and the door 6 in. high. A number of other types of heat-treatment furnaces are shown by this firm. The increasing development of electricity for industrial heating has caused intensive research work in the use of gas and oil for similar purposes. This has been facilitated considerably by improved efficiency in furnace construction, a noteworthy example being a high-speed steel furnace for tool hardening at a temperature up to 1,350° C. in its lower chamber, and 875° C. in the upper one. This furnace is one of many types exhibited by British Furnaces, Ltd.; the main features of it are rapid heating, uniform temperature, control of atmospheric proportioning of the gas and air.

The largest electric furnace that has ever been shown at any exhibition in Great Britain is a Gibbons-Wild-Barfield furnace. This furnace measures 9 ft. 6 in. long by 8 ft. wide by 6 ft. high, and the maximum input is 110 k.w.; the power to maintain 900° C. being only a small fraction of this amount. The heating elements are of heavy-gauge nickel-chrome, situated not only in the roof, walls, and floor, but also in the door to extend the useable length of the chamber to a maximum; those under the floor being enclosed, while the remainder are exposed. The heat insulation is graded according to its position in the furnace, and is so blended to reduce radiation losses to a minimum.

The door is electrically operated by means of push-button controls, the motive power being 1 h.p. Squirrel-cage motor of the Crypto Electrical Co., Ltd., manufacture, while the switchgear is of Brookhirst design. The door itself is of novel form, and presents many advantages over the ordinary type of plug door. An interesting feature lies in the fact that it can be opened and closed by the operator at the control end of the Gibbon's-Van-Marle charging machine, which is used in conjunction with the furnace,

and much time and labour is thereby saved. In addition full automatic temperature and time control is fitted which again reduces labour and running costs.

This furnace, together with various types of Wild-Barfield electro-magnetic hardening furnaces and high-speed steel-hardening equipments, will be in operation; while demonstrations will be given on the Vickers Pyramid hardness-testing machine, for which this firm are distributors.

An interesting exhibit is a Revergen furnace by the Davis Furnace Co. This furnace, which is of the oven type, is fitted with an electrically operated automatic reversing gear, especially designed to meet requirements; in addition, it includes an electrically operated automatic temperature control. The whole furnace represents the application of gas to general industrial operations in a most advanced form.

Oil-firing necessitates a larger combustion chamber than in gas-fired furnaces, and hot primary and secondary air is generally used. Lucas Furnaces, Ltd., are exhibiting oil-fired furnaces which embody many new features, and include a high-speed steel heat-treatment furnace designed on the latest principles. This design embraces recuperation, and an improved coke breaker and mixer. The furnace is practically noiseless, besides the most important feature of being non-scaling or oxidising. Oil-fired furnaces that have been installed by this firm are claimed to be capable of very close adjustment. On one large furnace 5 ft. 6 in. by 20 ft., a variation of 10 degrees plus or minus is obtained over the whole of the area right to the door, with an added advantage of no heat losses when the door is open. This latter advantage is due to the use of a patent frontal screen and recuperator.

In addition to those furnaces more especially designed for heat-treatment purposes, a wide range of furnaces is exhibited covering a variety of uses.

Foundry Exhibits.

Among the new features having special reference to the production of coatings is a sand conditioner exhibited by Pneulec, Ltd. It is a direct-coupled machine with a 3-h.p. totally enclosed electric motor placed overhead away from sand and dust. The machine is designed either for standing on legs or for suspension from a crane-hook, and is easily portable. The actual work of disintegrating is performed by mild-steel pins, and it is important to note that there are no stationary pins, but that all are mounted on, and revolve with, the machined plate. Scrap which gets into the machine discharges itself with the sand, without any damage being caused to the interior. There is no possibility of wedging with consequent damage, as would be the case were revolving and stationary pins employed. Any sprigs which accumulate around the pins are easily removed, as the hood is split and both halves hinged, so that there is complete and instant accessibility. This machine is shown in operation.

This firm also demonstrate a magnetically operated squeeze strip moulding machine. It undoubtedly represents an important development in moulding equipment, as in operation it is not only claimed to be perfect, but its cost is less to operate and maintain than moulding machines operating on other power. This magnetically actuated machine has a positive action, no jerk on either squeeze or draw, and it is controlled by press-button.

In regard to power, the standard machine is wound for d.c. supply, and at 240 volts pressure takes about 100 amps. for squeezing. The power actually consumed is very small, as operation is a matter of seconds only. Boxes up to 27 in. by 18 in. can be accommodated, and other sizes of machines are in course of construction.

Other specialities of this progressive firm exhibited include their Royer sand mixer, an oilsand mixer of the blade type, a direct-coupled swing grinder and part of a cupola. It represents the bottom section of a 3 ft. 6 in. dia. cupola, and is notable for the tuyère arrangement. On this cupola the tuyère is placed immediately below, instead of inside, the belt. The blast is led to the tuyère from the belt by means of a cast-iron bend. In each bend is fitted a regulating valve, giving proper individual control, and there are sight and poking holes of ample size. It will be seen that with tuyères arranged in this way it is impossible for slag to get into the belt, and that the cupola-man has good sight of the working of his furnace.

A number of small single-acting compressors are exhibited by Tilghman's Patent Sand Blast Co., Ltd., and this firm also has on view a 7-ft. dia. rotary table sand-blast machine, designed for operating at 80-lb. pressure. This type of plant is designed for cleaning flat castings, such as stove or grate parts, prior to vitreous enamelling. The table and apparatus embody several recent patents relating to the method by which the jets are traversed across the table, in such a manner that the table is evenly covered over its whole surface. The sand-blast apparatus also has a very special feature in a device that definitely separates the abrasive and dust, thus considerably increasing the cutting properties of the former.

A new totally enclosed dust-proof design of a sand-blast tumbling barrel is exhibited, with apparatus fitted with two nozzles; while a further exhibit is a new design of dust arrester provided with rigid cloth screens, which are easily removable.

Some new equipment is exhibited by Sir W. G. Armstrong-Whitworth and Co. (Engineers), Ltd., which includes a semi-rotary non-crucible type furnace for oil or gas firing. It is designed primarily for dealing with brass, and is constructed in sizes ranging from 200-lb. to 1,000-lb. capacity. Other furnaces shown are an iron crucible tilting furnace, specially designed for melting aluminium and its alloys and a crucible pit-type furnace.

New Electric Moulding Machine by Pneulec, Ltd.

An interesting feature is a die-casting machine which has been exploited by this firm recently. A special type for white-metalling railway axle-box bearings is shown in actual operation. The apparatus consists of three units by which the old metal is melted from old bearings, the heated shells are subsequently tinned by immersion in the tinning bath, and finally placed on the die-casting machine to enable the bearing metal to be forced into them.

Refractories.

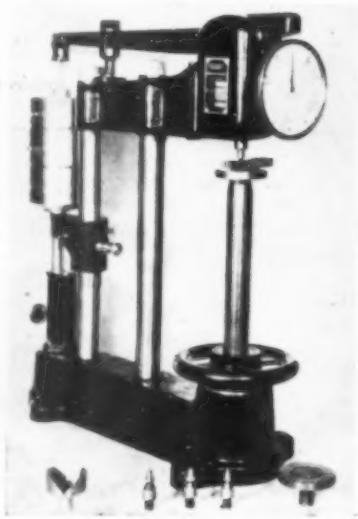
Samples of refractory products are exhibited, and Messrs. Gibbons (Dudley), Ltd., have featured an office constructed of firebricks and silica bricks. The exhibits will include: specials for Critt kilns and enamel melters; silicon carbide and corundum panel bricks for muffle linings, etc.; sillimanite bricks and tiles, and electric heat-treatment specials; cement furnace blocks, in aluminous and sillimanite materials; silica specials for gas-making and coke-oven installations; panel bricks and silica shapes used in heat-treatment furnaces, enamelling furnaces.

etc.; and samples of super-jointing cements for the cementing of bricks of all compositions.

All these refractories are classed according to definite compositions, and each has its special use. For example, the aluminous bricks are designed to withstand the severest conditions of temperature, corrosive dust action, and penetrative slag action: the sillimanite bricks are resistant to soda, lime, etc., but not to iron oxide or other molten metallic oxides; while "Alcor" corundum bricks are resistant to all the fusible oxides often found in fuel ash.

Welding and Cutting Machines.

The progress made in the use of alloy steels has necessitated continual development in welding technique and processes. The increasing employment of welding in fabricated structures is a definite result of this development, and in no direction has greater progress been made than with acid-resisting steels. These steels are a development of the ordinary stainless steels, which do not possess the properties demanded of steel for chemical plant. It is the chromium-nickel steels which possess the best acid-resisting qualities. As with other metals, all types of welding austenitic steels require absolute cleanliness of the part to be welded. The electric resistacne types present no great difficulties, although a somewhat closer temperature control than for mild steel is necessary. The oxy-acetylene process is satisfactory for thicknesses up to $\frac{1}{8}$ in., while the arc process can be used for $\frac{5}{64}$ in. and thicker steels. In all these processes a high standard of weld is essential, as imperfections may form resting places for foreign matter.



A New Hardness-testing Machine by Avery.

There are many things to be remembered about the oxy-acetylene process, if it is to be successfully carried out. A correct flame must be used and applied in the right way; the molten metal should never be allowed to boil, and adequate penetration should be ensured, while it is important to remember that austenitic steels have a coefficient of expansion about 50% greater than that of mild steels. In addition to alloy steels for chemical plants, high-tensile steels for pressure vessels and pipe-lines, manganese steels for resistance to wear, and many other special steels are finding increasing applications for welded design, each of these special alloys, however, must have its special welding technique.

Exhibits comprising a motor-generator set and transformer welding plant are shown by Murex Welding Processes, Ltd. In addition, an atomic-hydrogen welding plant and an automatic welding plant, as well as a large selection of electrodes. Demonstrations take place daily of oxy-acetylene welding of copper and automatic arc welding.

A new type of trolley for welding plants is being shown by Allen-Liversidge, Ltd., whose exhibit is incorporated with that of the British Oxygen Co. It has been specially designed for indoor use, and for work in confined spaces. The ingenious arrangement of the front and rear wheels enables it to be turned almost in the space of its own axis. There is an improved type of outdoor trolley which is very compact, and includes a detachable tool-box to hold the complete equipment.

A feature of this exhibit is a display of cutting machines for railway and structural steelwork. Railway and tramway engineers will be interested in the small portable oxygen cutting machine, specially designed for the cutting of manganese steel and other steel rails and joists. A 55-in. Universal oxygen cutting machine demonstrates on cutting jobs as applied to shipyards, railway works, and general engineering work. This machine is of special interest to manufacturers using forgings and castings, as any desired shape can be quickly cut from steel plate up to a thickness of 15 in., and so accurate is the cut that subsequent machining is reduced to a minimum.

Electrical Thermal Storage System.

The application of electricity to industry has made great strides during recent years, and a wide range of exhibits display the developments in apparatus arising from the desire to make more general use of this power medium. Of the many applications none have more interest than the model electrical thermal storage scheme. Messrs. Reyrolle have co-operated with Messrs. G. N. Haden and Sons, of Manchester, and, by the courtesy of the Birmingham Corporation Electric Supply Department, have installed a model heating scheme of this kind. The heater-tank is provided with a 15-k.w. bank of tubular immersion-type heaters connected to the three-phase exhibition supply, which is at 440 volts, 25 cycles. The storage cylinder has a capacity of approximately 700 gals., and is fitted with a thermostat or temperature device, which operates in conjunction with the contactor switch mounted on the control panel, to switch on and off the supply of current automatically, and thus to maintain the water at a suitable constant temperature.

The heater and storage cylinders are efficiently lagged with Messrs. Newall's 85% magnesia plastic lagging. In electrical heating schemes it is often necessary under tariff conditions to use the heater at certain periods only during the day. In such cases a time switch is incorporated and adjusted to operate the heater automatically, to comply with the tariff conditions. In this particular installation, a Venner time switch is mounted on the control panel.

A New Hardness-testing Machine.

Among the exhibits which are representative of the Avery products are two types of testing machines, which are especially designed for mass production. One is a visible self-indicating spring-testing machine, while the other is a new type direct-reading hardness-testing machine. Manufacturers have found it of great advantage to apply some form of physical test—particularly of hardness—to individual items in their production, and to do this it is not only desirable to have an accurate machine, but also one rapid in operation, and these requirements are claimed to have been met by the introduction of this new machine. It has been specially designed for rapidly determining the hardness of materials in terms of standard penetration numerals. These numerals are based on the depth of the impression produced by a standard penetrator under the action of a definite major load. This impression is superimposed on that produced by a definite minor load, so that errors due to surface imperfection of the specimen are eliminated.

In construction, the machine is comparatively simple, consisting principally of a standard carrying an adjustable table, a penetrator with a loading device, a depth-measuring gauge, a weight-lifting and releasing mechanism, and a loading-speed controller. The distance from the penetrator to the standard is 5 in., and specimens up to $4\frac{1}{2}$-in. thick can be accommodated. The impression on the specimen is so small that finished articles may be tested.

The possibilities of a hardness-testing machine of this type are very considerable, and should prove a great benefit to a wide range of industries engaged in mass production, providing it can be applied with ease in the various branches of engineering.

METALLURGIA

The British Journal of Metals.

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Subscription Rates for the British Isles - - - 24/- per annum, Post Free

FOREIGN SUBSCRIPTION RATES.

France	Fcs. 155	Canada	$6·20	Denmark	Kr. 22·80
Australia	25/–	Belgium	Belgas. 43·60	Norway	Kr. 22·80
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Austria	Sch. 43·50	Roumania	Lei 1025		

All the rates are subject to change without notice, according to appreciation or depreciation of the exchange.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at Kennedy House, Liverpool Road, Deansgate, Manchester.

Telegrams: "Kenpred," Manchester. *Telephone: Central 0098.*

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METALLURGIA
THE BRITISH JOURNAL OF METALS.

TRADE AND THE BRITISH INDUSTRIAL FAIR.

WILL the British Industries Fair this year be a trade turning point? That is a question that many people are asking themselves just now; but it must be remembered that the slump is not confined to Great Britain alone, but has now extended to every industrial nation of the world. Any improvement that can be effected therefore by the British Industries Fair will be a relative improvement, but this great national exhibition is having more international influence each year; it has now become representative of every phase of British industry, and visitors are attracted to it from practically all parts of the world. All do not attach the same degree of importance to the British Industries Fair, but the various industrial nations hold similar fairs annually, and it has become a necessity for our manufacturers to assemble their goods under one roof each year and to present, in effect, a common shop window for foreign buyers.

METALLURGIA
IS EXHIBITING AT THE
BRITISH INDUSTRIES FAIR
(BIRMINGHAM SECTION)
Row 17, Block E, Stand 6.
VISITORS CORDIALLY INVITED.

The British Industries Fair will prove to the world that our manufacturers are still enterprising, and of even greater importance, because it may be described as an experiment, is the British Empire Trade Exhibition, to be held in Buenos Aires, the opening ceremony of which will take place on March 14, and is to be performed by the Prince of Wales. This exhibition has been described as a striking example of national publicity, and that it should be organised in such times as these is rightly claimed to be creditable to all those responsible for its organisation.

It is all to the good that possible causes and remedies of the present trade depression should be discussed in both lay and trade newspapers. A writer in the *English Review*, discussing a national economic policy, urges that if we could increase our investments abroad to, say, £300,000,000 per annum instead of £94,000,000 as for 1929, by means of a carefully co-ordinated plan, we could increase our visible exports by £200,000,000 per annum. And this would result in more orders being placed for engineering and iron and steel products, electrical equipment, and other British manufactures.

It is significant that there has been less blame placed on manufacturers recently for inefficient equipment and organisation, while attention has been focussed more on the financial aspects of the trade situation. Thus we find that at the annual meetings of the big banks the chairmen have stressed the effect of the maldistribution of the world's gold. Mr. Reginald McKenna, the Chairman of the Midland Bank, has always been able to visualise the true relationship between banking methods and the requirements of trade and commerce, and, in his opinion, we are suffering from maldistribution of gold, due to the relative inability or unwillingness of creditor countries to loan to debtor countries. Then the public has not yet recovered from the American Stock Market collapse, and, secondly, we are still feeling the effects of the long period of deflation in this country. The optimistic strain of Sir Harry Goschen's speech at the annual meeting of the National Provincial Bank was heartening. Sir H. Goschen comes out definitely on the side of protection: "It was unfortunate," he said "that our fiscal policy was subject to party discussions and politics, but we must take things as they are, and now that it had been widely recognised that universal Free Trade was an unattainable ideal, some measure of protection should, and must, be extended to our trade, and that at an early date." Mr. C. F. Goodenough, of Barclay's Bank, made, in some respects, a rather reactionary speech, which was not very helpful. He expressed the opinion that the housing shortage, trade union restrictions, and unemployment insurance had tended to prolong unemployment. These factors have had an indirect effect because they interfere with the mobility of labour, but they are not causes; indeed, they would only be disturbing influences if there were a demand for our manufactures. A very sane view of the whole situation was taken by Sir C. T. Needham, of the District Bank, Ltd., who said that the depression being world-wide, its reactions were international, and the difficulties of one country accentuated, if they did not actually produce, the difficulties of another. The weight of taxation, already unduly heavy, has become more burdensome with the rapid fall in prices, and while economy has often been spoken about, it is very little practised, and national and municipal expenditure continues to rise.

Despite the spate of words in the Press and on the platform, the trade depression continues, and any improvement that may come about in the next few months will be at least partly attributed to the British Industries Fair, the Birmingham Section of which is of absorbing metallurgical interest; it will be an index of the progress that has been made by both ferrous and non-ferrous metal manufacturers during the past twelve months. It will afford an opportunity for all the important engineering and metallurgical associations in this country to hold conferences, and this is a good feature. It is claimed that there will be many entries of entirely new products to invite the interests of trade buyers, covering the whole range of industry, from great engineering or electrical plant to fabricated articles in a hundred thousand units, all ready for the showroom of the emporium of the actual trader. The exhibit of an important screw-making firm, it is of interest to note, is to be occupied not so much with the goods which have made them world famous, as to bring before trade buyers others of their products which are less known.

It is rather surprising that there should be a Canadian Section at the Briti h Industries Fair, and it is open to question whether this is in strict keeping with the object of the exhibition. There is no prejudice against Canada or any one of our colonies having trade exhibitions in this country, but the British Industries Fair is supposed to be representative of goods made entirely in this country.

Institute of Metals Annual Meeting.

THE Twenty-third Annual General Meeting of the Institute of Metals will be held in the Hall of the Institution of the Mechanical Engineers on March 11 and 12. Following a business meeting, a number of papers will be presented and discussed, while the Annual Dinner and Dance at the Trocadero Restaurant, Piccadilly Circus, W.1, will take place on the evening of the first day. The second day will be wholly devoted to the discussion of further papers presented at the meeting.

The range of papers expected to be submitted at this meeting is very comprehensive, including "The Results of Further Investigations of the Effect of Impurities on Copper," by Messrs. S. L. Archbutt and W. E. Prytherch. This research work by the British Non-ferrous Metals Research Association has been in progress some considerable time. Its object is to determine the effect produced on the physical properties of copper by the addition of small amounts of various selected elements. The investigations of the separate and individual effects of a number of impurities have been completed, and one of the papers to be presented at this meeting gives the results of the last, viz., "The Effect of Antimony." Further research work on the subject is devoted to the combined effect of two or more impurities. Of these, that on the combined effect of antimony and arsenic has been studied, and the results obtained form the basis of a second paper to be presented. "The Rolling of Alloys of Copper and Phosphorus," by Mr. Owen W. Ellis: "The Corrosion of Early Chinese Bronzes," by Capt. Wm. F. Collins; "The Solid Solutions of the Copper-Silver System," by Mr. D. Stockdale, are among the papers dealing primarily with copper alloys.

The constitution of the ternary system, silicon—aluminium—copper, has been studied at the Research Department of Woolwich, and Mr. L. J. Brice is presenting a paper containing the results of this investigation. Further work on various aspects of aluminium will be discussed in papers by Messrs. J. D. Grogan and D. Clayton on "Dimensional Stability of Heat-treated Aluminium Alloys," by Professor D. Hanson on "The Flow of Aluminium at Elevated Temperatures," and by Dr. K. L. Meisoner on "The Effect of Artificial Ageing upon the Resistance of Super-duralumin to Corrosion by Sea-water."

The constitution of the cadmium-rich alloys of the system, cadmium-silver, has been investigated by Mr. P. J. Durrant, and the results are to be presented in a paper. In addition to the foregoing other subjects to be considered will undoubtedly create considerable discussion,

GREAT LOSS TO INDUSTRY.

Industry has lost by death two of its most prominent personalities in Sir Charles Parsons, inventor of the steam turbine, and Sir Arthur Dorman, one of the most active and vigorous builders of the Cleveland iron and steel trade.

Sir Charles Parsons will ever be remembered for the scientific genius which he applied so successfully to industrial enterprise. He was the first engineer to receive the Order of Merit, and his name will be written in history with that of James Watt, and other men of genius.

Sir Arthur Dorman, on the other hand, approached engineering from the practical point of view. He fitted himself to become a leader in the iron and steel trade. His intimate working knowledge, indomitable courage, and adaptability of mind, enabled him to anticipate the immense possibilities of bridge building, and he did much to place the Cleveland Iron and Steel industry in a position to compete in meeting the world's needs in steel products.

The British Empire, and Great Britain in particular, can ill afford to lose such illustrious men; both have served long, and their memories will endure in all continents.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Feb. 20. Annual General Meeting. Report of Council for 1930. "Investigation of Steels for Aircraft Engine Valve Springs," by Capt. Andrew Swan (and others).

INSTITUTION OF MARINE ENGINEERS.

Mar. 6. Annual Dinner at Connaught Rooms.

Mar. 10 "The Efficiency and Steering Effect of Inward and Outward Turning Screws," by Mr. G. S. Baker, O.B.E., of the William Froude National Bank.

INSTITUTE OF METALS.

Mar. 11. Twenty-third Annual General Meeting. 10 a.m. in the Hall of the Institution of Mechanical Engineers, Storey's Gate, London, S.W. 1. Annual Dinner and Dance. 6-45 p.m., at the Trocadero Restaurant, Piccadilly Circus, W. 1.
Twelfth Annual General Meeting (Continued).

Feb. 26. Birmingham Section. J. L. Williams, "Press Tools for Sheet Metal Working."

Mar. 12. London Section. C. J. Smithells, M.C., D.Sc., "Gases in Metals."

Mar. 10. North-east Coast Section. R. D. Burn, M.Sc., "The Extraction of Copper." Annual General Meeting.

Mar. 9. Scottish Section. Annual General Meeting. Open Discussion.

Feb. 16. Sheffield Section. Conjoint Meeting for a discussion on "Refractories for Heating and Melting Furnaces."

Mar. 10. Swansea Section. Prof. F. C. Thompson, D.Met. M.Sc., "Some Researches on the Wire-drawing Process."

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Feb. 27. "Engine Seatings," by Dr. J. Montgomery, D.Sc., Chief Ship Surveyor, Lloyds Register of Shipping.

Mar. 5. "Variations of Efficiency of Propulsion with Variations of Propeller Diameter and Revolutions," by Rear Admiral, D. W. Taylor, C.C., U.S.N. (ret.). Hon. Fellow in the Lecture Theatre of the Literary and Philosophical Society, Newcastle-on-Tyne.

INSTITUTE OF BRITISH FOUNDRYMEN.

Feb. 23. Birmingham Branch. (1) Visit to a works in Coventry. (2) Lectore: "The History of Melting Furnaces," E. M. Currie, and W. G. Morgan.

Feb. 28. East-Midlands Branch. "Testing Castings," F. C. Edwards, Birmingham (at Derby).

Mar. 7. Annual Dance (at Loughborough).

Mar. 7. Lancashire Branch. "The Blast Furnace, its Limitations and its Relation to the Cupola," by Major H. G. Scott, Middlesbrough.

Mar. 13. Middlesbrough Branch. "Some Practical Notes on Cupola Plant and Material Control," by W. H. Poole, Keighley.

Feb. 28. Newcastle-on-Tyne Branch. "The Deterioration of Grey Cast Iron on Repeated or Prolonged Heating," C. E. Pearson, Newcastle-on-Tyne.

SCOTTISH BRANCH.

Mar. 7. "Patternmaking and its Relation to Design and Foundry Practice," by M. Russell.

Feb. 28. Wales and Monmouth Branch. "Interesting Moulding Jobs," W. Jackson, Exeter. (at Bristol).

Mar. 14. "Non-ferrous Alloys," Wm. Williams, Cardiff. (at Newport).

INSTITUTION OF WELDING ENGINEERS.

Mar. 12. "Cast-Iron To-day," Paper by Dr. A. B. Everest. At the Institution of Mechanical Engineers, Storeys Gate, London, S.W. 1.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.

Mar. 4. Sessional Meeting. "Public Baths and Wash Houses; Engineering Equipment and Data," Mr. W. E. Fretwell and Mr. E. Shutt.

ROYAL AERONAUTICAL SOCIETY.

Feb. 26. "Meteorological Aspects of Gliding and Soaring," by Capt. F. Entwistle, B.Sc. (Joint Meeting with British Gliding Association).

Feb. 24. Manchester Branch. A paper on Machine Tools. Messrs. Alfred Herbert, Ltd., at Newton Heath Senior Technical School, Newton Heath, Manchester.

Reviews of Current Literature.

Heat Treatment in Forging Steel.

THE heat-treating of steel has become a very important subject and since forging steel embraces an exceedingly wide range of carbon and alloy steels, the title of this work is apt to convey the impression that a very comprehensive consideration of the subject is to be found within its pages. This would be contrary to the wishes of the author. His intention is to give instruction in the handling of steel after it has been rolled into blooms, billets, and bars. The information concerns primarily the work of the smith, and should not be considered as a treatise on heat-treating. The author, who was formerly the shop manager of the smithing and forging departments at one of the important railway works, has attempted to give the practical man some information on the changes in the structure of steel that occur as a result of heating, and, in the chapter on handling, some very instructive examples are given on various classes of work which illustrate the need for careful treatment of the steel for forging.

The preliminary chapter deals very briefly with the manufacture of steels rather than their preparation, and, strange to say, no mention is made of steel made in the electric furnace. That referred to as cast steel, covering all steels having a content of over 0·5% carbon, being made in crucible furnaces. This is evidently an oversight, as, however briefly the subject is considered, the use of electric furnaces cannot profitably be omitted if other types of manufacturing plant are mentioned. Other chapters deal with casehardening, welding, testing, muffle furnaces, temperature measurement, and pyrometers, calculating the material required in a forging, and the work concludes with definitions of some terms used in the treatment of steel.

The chapter on temperature measurement, which contains quite useful information, occupies too much space in a work of 115 pages; it could have been reduced with advantage if only to increase the chapters on handling, casehardening, or welding; nevertheless, there is much that is of value to the practical man, and its perusal will assist the smith to understand his work better.

By B. Saunders. Published by Messrs. Crosby, Lockwood and Son, Stationers, Hall Court, Ludgate Hill, E.C. Price 5s. net.

Practical Metallurgy.

THE internal structure of metals and alloys is readily revealed by examination under the microscope, and the micro-structures, provided that the compositions are accurately known, prove a most valuable guide to the treatment, mechanical or thermal, which the metals or alloys have received, or in determining the most suitable treatment for particular metals. The micro-structure is more conveniently examined after its image has been projected on a photographic plate and reproduced in the ordinary way. The study of metal structures, known at metallography, deals with the constitution and structure of metals and alloys and their relations to the physical, mechanical, and chemical properties. Metallography has facilitated systematic investigation, and has assisted in the development of many alloys which were formerly only laboratory curiosities, making them compositions of general use.

There is undoubtedly a growing demand for a well-illustrated laboratory manual and reference book dealing with this subject, and this work, by Dr. N. E. Woldman, should not only prove valuable in schools and colleges covering courses in physical metallurgy and metallography, but also an excellent means of comparison and a reference book to metallurgists. The work is the result of courses on these subjects given to the student officers of the Postgraduate School of the United States Naval Academy by the author, when Head of the Department of Metallurgy and Chemistry. After a careful perusal of this book, we are bound to say that, if all subjects covered by the students at the United States Naval Academy are dealt with, in a practical way, as thoroughly as in physical metallurgy and metallography, the tuition is of a very high order. Nevertheless, the work could have been improved with the addition of some experiments on the determination of critical points, together with methods for obtaining electrical conductivity measurements.

The book is divided into groups of experiments according to the class of alloys to be studied. These experiments are preceded by eight experiments on the study of the microscope, preparation and microscopic examination of alloy specimens, preparation of microphotographs, cooling curves and thermal equilibrium diagrams, microscopic examination of metals and alloys, eutectic and eutectoid structures, calibration of noble metal thermo-couple, and thermal critical points in steel. In addition, experiments are included on carburising and nitriding of steels, welding, brazing, and soldering, defects and failures in metals, high-power metallography and X-ray metallography. The photomicrographs in this book, of which there are a large number, are excellently reproduced, and in consequence each conveys much of the information it is desired to portray. These are supplemented with text which explains the history of the specimen as much as possible, and discusses its microstructure, chemical analysis, physical properties, and uses. Following the discussion of each class of alloys the corresponding thermal equilibrium diagram is given, together with the physical property curves. The author makes a mistake in stating that all light aluminium alloys capable of being hardened by heat-treatment followed by ageing, have the commercial name of duralumin.

The experiment on high-power metallography has for its purpose the study of the structural characteristics of austenite and martensite in an iron carbon alloy, and as the photomicrographs illustrating the results were produced at very high magnification, much valuable information is portrayed that is not visible on a photomicrograph of low or medium magnification.

The principles of radiography are discussed. Rapid progress has been made, and its potential value is very considerable for determining the structural composition of an alloy, whether it is crystalline or amorphous; single crystal or aggregate; its crystal lattice-structure and dimensions; purity; chemical identity in regard to whether compound, mixture, adsorption, complex or solid solution; as well as other important information regarding grain size, internal strain, uniformity of composition, chemical changes, and the differentiation of good and bad materials.

This work should be seen by all interested in the subject and particularly by those responsible for teaching it. By Norman E. Woldman, Ph.D. Published by Messrs. Chapman & Hall Ltd., 11, Henrietta Street, Covent Garden, London, W.C. 2. Price, 17s. 6d. nett.

Transactions of Institution of Engineers and Shipbuilders in Scotland.

VOL. LXXIV. PART II.

THREE interesting papers are included in the "Transactions of the Institution of Engineers and Shipbuilders in Scotland for January, 1931." The first of these, by James Holmes, B.Sc., is entitled "The Turbo-Compressor as Supercharger," and was delivered on November 18, 1930; the second is "Some Non-Ferrous Engineering Alloys, and was read by Wesley Lambert on December 2, while the third, "Electrical Propulsion for Small Vessels," was delivered on December 16 by W. H. Woolnough. In addition, a discussion on a paper entitled "Manœuvring of Ships, Part IV.," is reported.

The New Alloys and——— Machine Tool Design

By Francis W. Shaw, M.I.P.E.

Part III.—Factors that Control Output.

Analysis of factors that build up non-cut-time and production time. Effect of multiple tools and the distribution of total time on large work. High power milling cutters are considered.

OUR previous instalment indicated, *inter alia*, how equal and simultaneous cut-time and non-cut-time decreases have a far greater influence—a seemingly disproportionate influence—on output than a simple reduction of either.

May we reinforce our conclusion by conceiving the impossible to be possible—that both are eliminable? Then the output plotted against time would manifestly be infinite, whereas elimination of either, when they are equal, could but double the output. Even small concurrent reductions are worth considerable effort to get, and it is not surprising, therefore, that more study than ever is now being given not only to the problems borne by the increased speeds and feeds the new alloys have rendered possible, but the very pregnant problems that these have conspicuously magnified.

The trend of the improvements as foreshadowed by the initial attempts to meet the new conditions, and which theoretical study would demonstrate to be possible, an analysis of the factors that go to build up the non-cut-time should disclose.

Non-cut-Time Factors.

The non-cut-time factors are variable for different machines, work and processes, and may be grouped into: (*a*) those applying to a run of work, and (*b*) those chargeable to each work-piece.

In the (*a*) group fall the—

1. *Study factor.*—Studying drawings, operations and methods.

2. *Equipping factor.*—Applying tool- and work-holding devices and tools.

3. *Adjusting factor.*—Positioning tools, work-holders, speed- and feed-control mechanism—stops, dogs, cams.

4. *Re-setting factor.*—Removing worn tools and re-setting them, readjusting machine and equipment.

5. *Waiting factor.*—Seeking or awaiting material and tools.

6. *Personal factor.*—Time in which the machine is inoperant, though "operable," and for which the operator is avoidably or unavoidably responsible.

7. *Cleaning factor.*—Time in which the machine is standing while cuttings are being removed, or while being cleaned.

8. *Upkeep factor.*—Lubricating, repairing, maintaining coolant supply.

9. *Scrap factor.*—Replacing spoilt work.

10. *Fatigue factor.*—Loss of output due to mental or physical inertia or lassitude due to study or operating the machine, or handling the work.

11. *Skill factor.*—Allowing for differences in skill, care or dexterity of operator or tool setter.

In the (*b*) group fall the—

12. *Chucking factor.*—Inserting, securing and removing the work-piece.

13. *Operating factor.*—Starting, stopping or braking the machine, applying and withdrawing tools or slides.

14. *Checking factor.*—Examining, gauging and measuring the work-piece.

15.—*Handling factor.*—Cleaning, binning or otherwise storing the work-piece ready for removal from the machine.

All these factors apply to every type of machine, be it hand-operated, semi-automatic or automatic, their incidence depending not so much upon the degree of the automaticity—or lack of it—as on the type or size of the machine or the work-piece, on work differences, on the works' organization, and now, more than ever, for a given type or size of machine or work, upon the design and construction of the machine.

An analysis of the operations involved in the production of definite pieces of work may yield an inkling of the incidence of the factors, and, consequently, of the desirable trend of improvements.

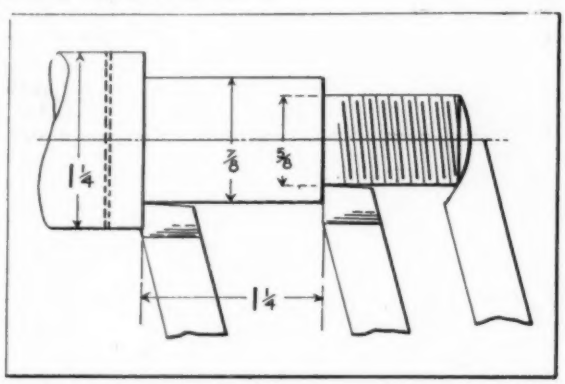


Fig. 8.—Turning a Simple Stud in a Simple Lathe with Three Tools.

Production Time Analysed.

Our analysis shall begin with a simple piece of work produced in large quantities on simple lathes.

Fig. 8 shows a stud to produce which necessitates turning, forming and screwing operations. The blank, cut from bright-drawn mild-steel bar, forms two pieces, to be subsequently separated—an operation now ignored. For each stud the following operations are required. The blank is held in a universal (self-centring) chuck—hand-actuated. Screwing is by a self-opening diehead mounted on the tailstock—lever-operated. The turning speed, based on the 1¼ in. dia., is about 200 ft. a min., the spindle turns being 600 a min. The feed for each spindle turn is about 0.012 in., the time, based upon the length of the longest step (1¼ in.), thus being about 10 sec. For screwing, the work makes 100 turns a min.; to screw 10 threads, therefore, occupies 6 sec. The total cut-time is, accordingly, 16 sec., quite invariable under the stated feed and speed conditions.

But what can be said of the non-cut-time? To the nearest second, each element, repeatedly performed, was observed to occupy the time detailed in Table IV. The figures represent the time which would be spent if the tabulated operations were uninterrupted and, since the test was by a dextrous operator, may be regarded as the theoretical minima.

The theoretical non-cut-time factors of Table IV, it will be noted, all appear in the (*b*) group. If machines were automatic and none of the (*a*) factors entered into production, the factors would never vary, and the output would therefore always be at the rate of one piece in every 40 sec. And the inclusion of the (*a*) factors would hardly affect the result, unless, as is rarely the case, they bulk

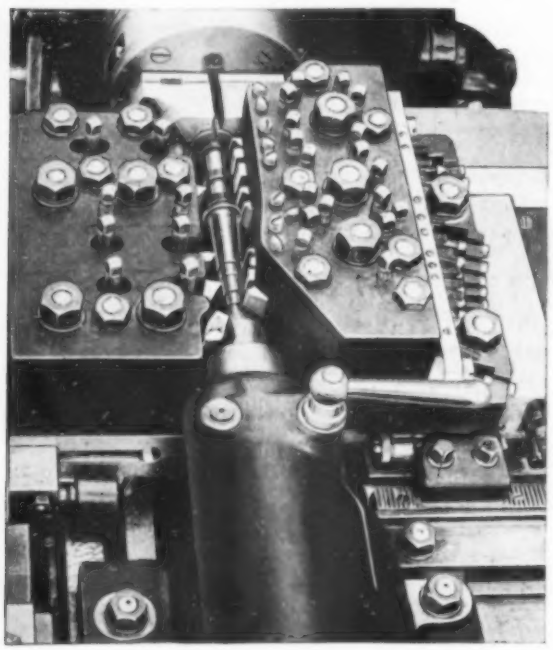


Fig. 9.—Thirteen Tools Simultaneously Cutting on Loewe Multi-cut Lathe (George H. Alexander Machinery, Ltd.).

large, for they are divisible by the number of pieces in the run. The theoretical total in the tables might consequently be fairly made the basis for comparison for the different cases tabulated—the point of 100% efficiency, so to speak. Clearly, then, whenever this perfect efficiency is not attained, the loss may be looked for, not among the (*b*) factors, but in the (*a*) group.

TABLE IV.

ANALYSIS OF THEORETICAL TIME.

	Seconds.
(*a*) Chucking—factor (12)	5
(*b*) Starting machine—factor (13)	2
(*c*) Applying cut and feed—factor (13)	2
(*d*) Withdrawing tools—factor (13)	2
(*e*) Stopping machine—factor (13)	2
(*f*) Removing piece—factor (12)	3
(*g*) Checking—factor (14)	5
(*h*) Cleaning and binning—factor (15)	3
Total non-cut time	24
Total cut-time	16
Theoretical total time	40

Some reader may remark that, though we are illustrating a simple job, three tools are in simultaneous operation, whereas in ordinary lathe practice but a single tool would be cutting at any time. That is true. But, in ordinary lathe practice, where the work is mounted between centres, as in our example, complications exist, well known to the practised turner, which prevent the fullest utilisation of the tool's cutting capacity.

Output increase commensurate with recent rises in cutting values can only follow systematic organisation of the processes with concurrent and appropriate modifications in the design of even the simplest lathes.

Our last statement is not strictly true if Widia be the replacing medium, for some output increase is possible from the older machines. It is not generally known or realised that for a given cut, Widia is subjected to but half the pressure high-speed steel receives, from which it follows that, since bearings are subjected to lower stresses, the work, with certain exceptions, can be run at higher speeds, speeds more appropriate to Widia. The yield of the work, too, is less and, consequently, more tools could be in action together.

Effect of Multiplying Cutting Tools.

In order effectively to study the result of increasing the number of tools cutting together, pieces of somewhat larger dimensions shall be considered.

First, let us merely lengthen the piece of Fig. 8, leaving diameters unchanged. With three tools in action, as shown, doubling the length of every step would double the cut-time. The non-cut-time would be increased very little, for the augmented cut-time would allow more time for recuperation from the greater fatigue due to handling heavier pieces, and most of the other (*a*) factors would be unnoticeably affected.

Second, imagine the piece doubled in diameter only. Again the cut-time would be doubled without appreciable change in the non-cut-time, for if the cutting speed is to remain the same, the spindle speed must be halved.

TABLE V.

TIME TAKEN CONTRASTED WITH THEORETICAL TIME.

	Seconds.
(A) Theoretical time	40
(B) Special test time—½-hr. run	75
(C) Ordinary test time—2-hr. run	145
(D) Time allowed—4-hr. runs	290
(E) Time taken—minimum	110
(F) ,, average	180
(G) ,, maximum	230

The only effect of dimensional change has been to lessen the disparity between the cut-time and the non-cut-time. The disparity still glares at us, however, if the cut-time be compared with the total average actual time which now will be 180 + 16 sec. = 196 sec., the cut-time being 16 sec. × 2 = 32 sec., as will be seen from Table V., as against 180 and 16, the numbers of seconds for the smaller work. Further improvements in cutting materials can only reduce the cut-time, and therefore intensify the disparity.

A typical set-up of tools in a modern multi-cut lathe is illustrated by Fig. 9. Here no fewer than 13 tools appear in simultaneous operation, the four tools in the front tool block feeding along the work-piece, while the nine tools in the rear block feed inwards, turning the shoulders or facing the collars of the work-piece.

Fig. 10 illustrates the stages in turning an engine camshaft from a cut-off and centred bar. The bar, if long compared to its finished diameter, is first "spotted"—an operation which may be performed in a simpler lathe—to afford points of support against the bending stresses induced in cutting with so many tools. The shaft is

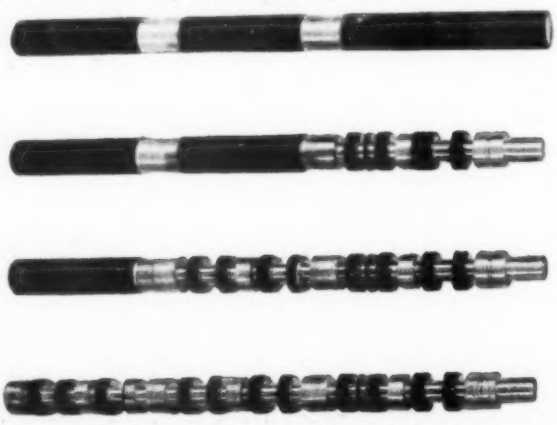


Fig. 10.—Stages in Turning a Camshaft in a Loewe Multi-cut Lathe.

completed at three settings, the figure illustrating its change in appearance at the three settings.

Fig. 11 shows the tool set-up for another camshaft in which all the turning except the initial spotting is performed by feeding the tools inwards, and Fig. 12 a typical set-up for a piece rather longer than that seen in Fig. 9, so demanding support from a steady. In this shaft, made from a forging or stamping, some of the steps are so long that in-feeding would be impracticable for all the cutting, and for this reason, the front tools are fed along the work-piece as the rear tools feed inwards. As the longitudinal travel is limited by the length between the cams, an additional tool *A* shares the work on the longest step, whose length exceeds the cam spacing. Dividing the cut in this manner is a familar device, even where travel-distance restrictions do not exist, to reduce the cut-time.

If we assume, quite legitimately, a cutting speed of 80 ft. a minute, and an in-feed of 0.005 in. for each turn of the bar or forging, $3\frac{7}{8}$ in. diameter, the step-depth being 1 in., to feed this distance would occupy about $2\frac{1}{4}$ min. (Messrs. Loewe place the cut-time at $1\frac{1}{2}$ to 4 min. for each section of camshafts of various sizes).

TABLE VI.

NON-CUT-TIMES COMPARED.

	Seconds.
(1) Theoretical	24
(2) Special test	31
(3) Ordinary test	129
(4) Average actual	164

Now, the average non-cut-time on the small stud of Fig. 8 was 164 sec. (Table VI). As any one of the camshafts is many times heavier than the stud, we may expect a little addition to the non-cut-factors and, therefore, 3 min. would not be an out-of-the-way estimate for their total. Thus, out of $5\frac{1}{4}$ min. but $2\frac{1}{4}$ min. would be occupied in cutting. These times would, of course, be multiplied by the number of sections—in Fig. 10 shaft three, in Fig. 11 and 12 shaft two each. For our present comparison, each section can be regarded as a separate work-piece.

Again do we see that the saving to be effected by any further improvements in cutting materials will not

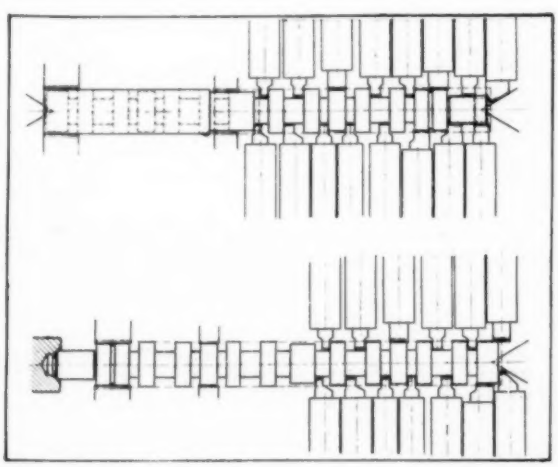


Fig. 11.—Camshaft Being Turned from a Bar by In-feeding all the Tools.

materially affect the output. This time for an additional reason—the speed and feed restrictions imposed by the work itself, as was explained three paragraphs "ago." And still more apparent are the advantages that must follow the introduction of devices for reducing the non-cut-time factors.

The Distribution of Total Time on Large Work.

Generally speaking, the larger the work-piece, the larger looms the saving the new alloys can effect, and of more consequence, then, become efforts to meet speed increase, and less essential non-cut-time reductions.

Fig. 13.—A B.S.A. Spiral Cylindrical Milling Cutter at Work, Showing the Needle Formation of the Chips.

TABLE VII.

RATIO OF NON-CUT-TIME TO CUT-TIME.

(R 1) Theoretical	16 : 24 = 1 : $1\frac{1}{2}$
(R 2) Special test	16 : 31 = 1 : 2
(R 3) Ordinary test	16 : 129 = 1 : 8
(R 4) Average actual	16 : 164 = 1 : 10

Consider, as one instance, a piece of work weighing many tons, the metal to be removed measurable in tons. A day, days; a week, several weeks, may tools be engaged in cutting; and at the most, a few hours spent in preparation, in reconditioning tools, in removing cutting and in other factors constituting the non-cut time. Indeed, some of the factors are really not factors at all, for the work they involve can proceed concurrently with cutting. The only factors, then, that need severe study are those which would interrupt the cutting or demand the employment of additional labour—the removal of cuttings, for example, work a skilled operator objects to do even if, on long cuts, the machine is running without attention.

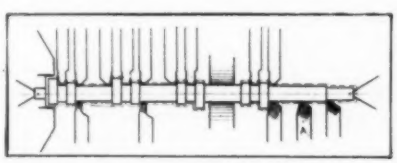


Fig. 12.—Turning Camshaft partially by In-feeding, partially by Traversing the Tools Endwise.

In Table VIII are compared the savings to be effected by reducing the non-cut-time only, the cut-time only, and both equally to a half their original values, from which it will be seen that whereas concurrent equal reductions have always the effect of halving the time, and that non-cut-time drops show smaller benefits than cut-time drops, when the time spreads into a week or more, practically all the gain is due to the cut-time drop, hence to the augmented cutting-speed the better cutting materials permit.

So far have been studied the rougher kinds of turned work, upon which the super-cutting materials make the best show. Fine cuts taken at high speeds are apt to be rough, and would not be acceptable for a "self-finish." Again, high speed is liable to disintegrate the surface, and

from "hair-cracks"—incipient fractures: dicta applying to most other machining operations.

TABLE VIII.

ILLUSTRATING INFLUENCE OF FALL OF CUT- AND NON-CUT-TIME ON OUTPUT OF LARGE WORK.

Cut-time hours	4	8	16	32	64
Non-cut-time hours	2	3	4	5	6
Total hours	6	11	20	37	70
Time saved by reducing non-cut-time by a half, %	16	14	10	7	4
Time saved by reducing cut-time by a half, %	33	36	40	43	46
Time saved by reducing both by a half, %	50	50	50	50	50

Fig. 14.—Alfred Herbert Spiral Cylindrical Milling Cutter of Large Spiral Angle, but with Radial Teeth.

Fig. 15.—Similar Cutter with Undercut Teeth.

Shock Cuts.

Now, consider the reciprocating type of machine tools—planers, shapers, slotters. Obviously, where the tool enters the work with impact, the speed is limited by the tool's power to resist shock rather than by its cutting capabilities. The poorer tool might, then, be as good as the better, where the shock stresses are little less than the tool material will bear. The tooling of scaly material liable to destroy quickly the ordinary tool's cutting edge would, however, justify the employment of the better cutting material. And, we fancy, that is where, rather than in a vast speed increase, Widia and other tungsten-carbide tools will show to advantage. And this seems to be proved by the fact that, though super-high-speed steel tools are capable of cutting cast iron at the rate of 200 ft. a minute, they would hardly be expected to accomplish work in reciprocating machines such as is being performed by Widia, one example of which, in the works of Alex. Stephen and Sons, Ltd., Glasgow, is the planing of cast-iron plates at speeds up to 230 ft. a minute, with a cut $\frac{3}{4}$ in. deep, and a feed of $\frac{1}{32}$ in. per cut.

Whilst to meet shock cuts on reciprocating machines is a problem concerning the tool rather than the machine, for shocks are but momentary, occurring at the beginning of each cutting stroke, on milling machines both cutter and machine are equally involved, for the shocks continue throughout the cut. With every increase in cutting speed, therefore, not only is attention needed to improvements in the cutter, but in the machine as well.

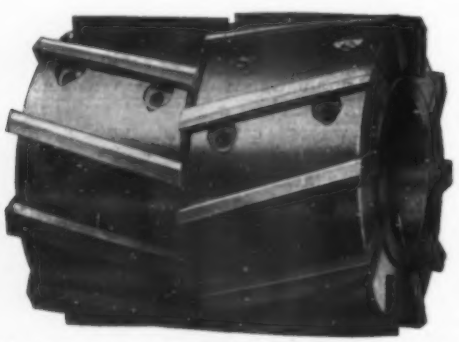
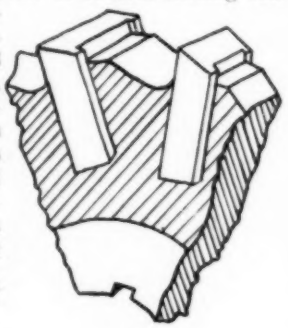


Fig. 16.—"Brooke Tool" Pair of Cutters with Inserted Blades of Super-high-speed Steel, Staggered and "Interlocked."

In the early days of milling, the cutter had teeth of small dimensions, closely spaced. Later, it began to be realised that close spacing resulted in many teeth being in simultaneous action, this compelling feed restrictions. And so we saw tooth-pitch gradually increase and the cut per tooth with it, introducing severer shocks. To some degree shocks could, however, be minimised by narrowing the cutters, multiplying their number, and arranging their teeth "staggeringly." Then came still larger teeth, and fewer, non-radial or helical, according to the type.

High-power Milling Cutters.

The provision for meeting shocks is well explained by the illustrations of milling cutters of several leading tool makers. The modern cylindrical cutter, with spirally-disposed teeth such as Fig. 13 shows, a product of B.S.A. Tools, Ltd., is capable of removing metal at an enormous rate in comparison with cutters of older type. In an Alfred Herbert No. 22 horizontal milling machine a cutter of this type $4\frac{1}{2}$ in. diameter operating on a bar of 35-ton steel 8 in. wide, will remove 32 cu. in. of metal per min.



A cutter with much increased spiral, applicable only to machines capable of withstanding the increased end-thrust large angles impose, is illustrated in Fig.14, and a note worthy improvement upon this, in teeth having non-radial (undercut) cutting faces, but still having a large spiral angle, Fig. 15 depicts in end view. This cutter seems a happy compromise between the shock-producing, non-spiral cutter operating without end-thrust, and those cutters of so great a spiral angle that they resemble screws rather than cutters, and demand inordinate provision against end-thrust. At the moment tungsten-carbide is difficult to apply to spiral cutters.

Fig. 17.—"Brooke Tool" "Cardinal" Cutter. As the cutter is ground, the body is milled away so as to maintain the chip clearance. But a small proportion of the high-speed steel is wasted.

Fig. 16 illustrates how greater cutting continuity and blade overlap at the meeting of the cutters are secured by staggering the blades of a pair of cutters, here a product of The Brooke Tool Manufacturing Co., Ltd. In these, as in all comparatively narrow cutters the blade grooves are merely inclined to the cutter axis, not spirally cut. With several exceptions, wide cutters are of the solid type, the exceptions being some American cutters in which spiral blades are cast in the bodies, and the Kendall and Gent cutter in which spiral blades fit in spiral grooves.

A novel departure in cutter construction, aimed at increasing the solidity of cutters with inserted blades, and getting the utmost value out of the more expensive material is that seen in the "Cardinal" cutter, made by The Brooke Tool Manufacturing Co. Fig. 17 shows how the blades, said to be "homogeneously amalgamated with the cutter body by fusion," are secured against tilting or sliding endwise, and how the blades can be ground time after time, the material of the body being gradually milled away to leave the requisite chip clearance, until very little is left of the blades as waste. True, the body, or, rather all that remains of it, is wasted, but this is a small loss compared with the loss of the inner portion of a solid high-speed steel cutter remaining after the teeth are gone.

(To be continued.)

Origin of Stainless Steels and Alloys

By J. Ferdinand Kayser, Assoc. Met.,

Chief Metallurgist to Darwin's, Ltd.

Discussion on the origin of stainless steels has been very considerable recently, and opinions have been somewhat varied. The author gives the results of a very thorough search which will assist in more accurate opinions being formed.

THE origin of stainless steels engaged the attention of the author 14 years ago when he set to work in an endeavour to discover the original investigators. During the course of his researches, reference was made to technical papers published as far back as the end of the eighteenth century and the beginning of the nineteenth century, and to patent specifications more than 80 years old. Stainless steels and alloys have formed the subject matter of patents for many years, and the list of British specifications alone contains references to more than 250 patents, and there are doubtless many obscure patents under unrecognisable titles which he has not yet discovered. The author gave the results of his researches in a lecture to the Rotherham Technical Institute Engineering Society on "The Origin and Development of Stainless Steels," in which he stated that stainless and corrosion-resisting ferrous alloys owed their properties to the presence of chromium and/or nickel, and that the discovery of chromium-alloyed steels and their subsequent development laid the foundation for the wide range of stainless irons and steels now available.

The corrosion-resisting properties of iron-chromium alloys have been recognised for more than 120 years. Chromium was discovered by Vauquelin about 1797. Between that date and 1815 Vauquelin experimented with chromium to a considerable extent, and came to the conclusion that, along with phosphorus and manganese, chromium was the cause of hot and cold shortness in wrought iron. In 1838 Mallet stated that it had been long observed how little liable to tarnish or rust native and meteoric irons were, which contained 9·5% nickel and variable proportions of chromium and cobalt. Fremy referred to the acid-resisting nature of chromium in no uncertain terms during 1857, and said that it was remarkable that, although strongly resembling manganese and iron in many respects, in the presence of concentrated acids it behaved more like rhodium and iridium, and that alloys of chromium with other metals often had the same hardness and resistance to the action of concentrated acids as chromium itself.

In 1872, the first provisional patent application was made for a corrosion-resisting steel containing chromium, but no final patent was applied for. If one followed the instructions given in that provisional patent specification one obtained a steel containing approximately 30% chromium and 1½% tungsten this steel being remarkably resistant to all forms of corrosion, quite independent of the carbon content. Many years previous to that, a patent had, however, already been granted for a steel which, in the words of the patentee, protected the "combining of iron with other metals to prevent oxidation." Alloys made according to that patent consisted of cast iron or steel to which had been added from 2 to 10% of tin or copper, or nickel, or antimony.

In 1888, John H. Hall, of Sheffield, was granted patent protection for a steel containing from 2½ to 50% of nickel together with chromium, silicon, manganese, and tungsten. In the patent specification no mention was made of stainless or corrosion-resisting properties, but it was stated that the purpose of the invention was to produce a steel with great strength and capable of receiving a brilliant polish. The product was suitable for cannon, gun barrels, shot and shell, and armour plates. There were continuous references to chromium and nickel steels throughout the nineteenth century, but the first really significant references to corrosion resistance did not appear until 1903, when, in a British patent granted to a French firm, the following most significant paragraphs appeared :—

"The most important modification to which these elements, nickel and chromium, give rise, consists in the important property (which forms the subject of researches of metallurgists at the present time) which they communicate to the said products, steels and irons, of presenting great resistance to corrosion.

"This quality adapts them for a number of purposes and uses for which irons containing carbon and manganese in greater or less proportions are only very imperfectly adapted by reason of their liability to corrosion, which is attributed, to a great extent, to the manganese which they contain."

The earliest evidence that chromium steels could be produced on a commercial scale was found in 1886, in a paper in the *Journal of the Iron and Steel Institute*, where Brustlein stated that chromium steels containing 16% chromium and 2·7% carbon had been supplied since 1877, and that such an alloy might be forged and might be classified under the heading of steel. Brustlein also stated that chromium steels scaled with much greater difficulty in tempering than ordinary steels. He did not say for what purpose such chromium steels were used.

In 1911, British Patent No. 11,063 was granted to Mr. P. R. Kuehnrich, protecting a steel containing from 2 to 3·5% of carbon, and from 13 to 17% of chromium. This was interesting, not so much from the point of view of the corrosion-resistance value of chromium, which was not mentioned in the specification, but from its value in indicating that a chromium steel was suitable for the production of cutting tools. The specification also contained the significant statement that chromium steels containing up to about 1·5% carbon and 8% or more of chromium were well known.

Dealing with the more immediate originators of present-day stainless alloys, the author mentioned, amongst others, Mr. Harry Brearley (of Sheffield), Mr. Elwood Haynes (U.S.A.), and Dr. Benno Strauss (of Essen, Germany). These gentlemen conducted their researches quite separately, and although, as learned metallurgists, they were doubtless influenced to some extent by previous workers, every credit was due to them for their work.

Elwood Haynes commenced his work some 30 years ago, and its history could be followed in a series of patents commencing in 1907. Mr. Brearley's history of his own early work was published in the *Sheffield Daily Independent*, February 2, 1924. Dr. Strauss has stated that he started on the supposition that it ought to be possible to make use of the valuable properties of chromium, that is, its resistance to the action of oxygen, for the purpose of increasing the resistance of iron against the attack of hot gases, in view of the fact that nickel had been rendered extremely heatproof by the addition of about 10 to 15% of chromium. In 1910 he first prepared alloys, containing from 0·10 to 5% nickel, and from 10 to 29% of chromium, which were found to exhibit remarkable corrosion-resisting properties. That work led to patents being applied for and granted for nickel-chromium corrosion-resisting alloys in all countries of the world. The British patents were Nos. 13413, 13414, and 13415, of 1913. The patentee named in the British patent specifications was C. Pasel, an employee of Fried. Krupp A.G., of Essen. A well-known

Sheffield firm manufactured a nickel-chromium steel under the protection of patents Nos. 13414 and 13415 until they expired a little more than a year ago.

In regard to the researches carried out in the Darwin Laboratories (formerly the laboratories of the Spartan Steel Co., Ltd.), in so far as austenitic corrosion-resisting alloys were concerned, the first casts were made about 1914. The early products were binary alloys of nickel and chromium, but during the past 16 years numerous modifications had been introduced, and their products now covered alloys containing from 8 to 60% of nickel, from 0 to 30% chromium, and from 0·1 to 1½% of carbon. No one alloy was suitable for all purposes. Corrosive influences varied so much that, in order adequately to cover engineering requirements, it was necessary to manufacture many different alloys, whose number would, he felt convinced, be still further increased as the peculiar advantages of the different analyses under special conditions became better understood.

It is interesting to note that Sheffield manufacturers had been very loth to take up the manufacture of the nickel-chromium alloys, and when the author first referred to them in a lecture to the Sheffield Metallurgical Association, approximately 10 years ago, and said that the stainless alloy of the future would not be a straight chromium alloy, but a nickel-chromium alloy, his remarks were received with scepticism. Present-day developments had, however, fully justified his prophecy and, undoubtedly, at the present time, the production of nickel-chromium stainless steels is much greater than that of straight chromium stainless steels.

The author takes a very optimistic view of the future of stainless and corrosion-resisting steels and alloys, and considers that their use is still in its infancy. In America they are better known and used to a much greater extent than in this country. To such an extent are corrosion- and heat-resisting alloys used in the United States that for a considerable time the prices of bars and sheets, etc., of the different qualities have been quoted along with the prices of steel rails, etc. Further, a greater range of alloys is found in America than is yet being exploited in this country. There, the cutlery qualities and the austenitic qualities, low-carbon iron alloys, containing approximately 30% of chromium, were, comparatively speaking, well-known products, whereas they were only just becoming known in this country.

There are several factors governing the rate at which these alloys can become of further use in industry, but it is incorrect to say that engineers' demands cannot be met by the metallurgists' products. Present-day metallurgical products more than meet the demands of engineers, but the price factor is a very real difficulty in the majority of cases. That applied to a much greater extent in England than in probably any other country. It certainly applied to a much less extent in the United States, where stainless and corrosion-resisting alloys were being produced in vast quantities.

Whilst there seems little hope that it will be possible to produce a cheaper stainless alloy by the discovery of a steel which would require the addition of smaller quantities of nickel and chromium, both of which were comparatively expensive, particularly the former, it is possible that, at any time, a metallurgical discovery may be made which will enable alloys somewhat similar to those at present on the market to be much more easily manipulated and manufactured into finished articles, and that would result in a lowering of prices and an increased consumption.

The directors of Sanderson Brothers and Newbould have appointed two new directors of the company. They are Mr. J. Harold Brown, a prominent Manchester business man, and Mr. John Waddell, who has had over forty years' service with the company. Mr. E. Sanderson Elam of London has resigned his seat on the board, owing to pressure of business.

The Stresses in Wire-drawing.

THE cold working of metal, and especially of steel for rope-making, has become of increased importance year by year. Wire, in all its forms and applications, has given rise to vast industries, and much of the world's wealth hangs on the mining rope. The use of the die for wire-drawing has been known for centuries, and such is its antiquity that wire rope for cranes has been found in Pompeii. The action of the die, however, is not yet fully understood.

To understand what happens, an endeavour must be made to examine how the flow occurs, and what are the stresses set up. What might be termed the kinematics of the subject have been developed of late years through the rise of the science of metallography. The crystalline structure of metals and their alloys has been investigated both in the aggregate and in the individual crystal, and the deformation of these crystals under strain has been studied. It is known that, as the result of shear or flow in certain families of parallel planes, a very great deformation of a single metallic crystal is possible, and hence, in the wire rod, which is a suitably prepared aggregate of crystals, a great extension is obtainable. There has been little or no dynamical explanation of this matter, and, in a paper delivered before members of the Institution of Engineers and Shipbuilders, in Scotland, Mr. E. M. Horsburgh, M.A., D.Sc., endeavoured to direct interest to this very important subject.

In wire-drawing, he stated, the wire is subjected to a tensile stress when being pulled through the die, but a compressive stress must also be produced from the die. During the course of his paper he showed that, for the light draughts usually employed, the compressive stress must have the major share in deforming the metal, and in assisting the tensile stress, to cause the material to flow through the die, and that the resultant deformation in the die would be due to the sum of these two effects.

Tool-steel Tools.

IN a paper delivered to the American Society of Mechanical Engineers, Mr. A. H. D'Arcambal laid particular stress on the importance of correct design in tool-steel tools. "Metal-cutting tools offered to the trade to-day," he said, "are vastly superior in quality to tools of a decade ago. Improvements in machine-tool design, tougher materials machined, and the demand for greater economy and accuracy, have all helped in the development of efficient tools. The quality of metal-cutting tools is governed by design, quality of steel used, and hardening treatment, and very special attention should be paid to these factors. Careful control of detail in design, such as relief, back taper and lands in boring tools is important, as results may be completely different according to the type of material being machined. Considerable economy can be effected by the use of tools suitable to this material. This is specially important in the case of reamers and taps: the latter are often run at drill speeds, and when even the oil used has an effect on the size of hole, it is obvious that correct design is essential. In the same way, the efficiency of metal-splitting saws is governed by the number and shape of teeth, amount of concavity, rake and finish. As regards quality, there are two types of steel commonly used to-day. These are plain carbon tool steels and alloy carbon tool steels, the former being excellent for "shock" tools, and the latter being used for tools where a slightly greater depth of hardening is required. High-speed steels vary according to their uses, there being demands for both 18% tungsten steel containing from 5 to 10% cobalt, and also for 13% tungsten, 2% vanadium steel. Most high-speed tools, however, are made from steel composed of about 0·70% carbon, 4% chromium, 1% vanadium, and 18% tungsten. The hardening room of a small-tool plant is one of the most important departments in the factory, and no expense should be spared in equipping it with the best of furnaces, pyrometers, quenching baths, etc., and organising it on the most efficient basis possible.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part V.—Rolling Ingots.

The types and sizes of aluminium rolling ingots used in practice are discussed in this article. Some information is given regarding the defects in, and structure of, ingots.

GIVEN good melting practice and proper composition of metal, the quality of aluminium and aluminium-alloy sheet is considerably dependent on the quality of the ingots from which rolled. So far, the problem of producing aluminium ingots as a preliminary step to sheet rolling has not been given the attention it deserves, and comparatively little improvement has been made either in methods of operation or in the design of ingots or moulds during the past 15 years. This is in marked contrast to the situation in steel-ingot production, where the subject has been studied at length. Although apparently a simple process, the production of good rolling ingots in aluminium and its light alloys is a matter involving sundry mechanical difficulties and various complex metallurgical problems.

While considerable fundamental information is available regarding the effect of various factors on the structural features of ingots cast in ferrous and cupreous alloys, singular to say little progress has been made in applying the known facts regarding other metals to the pouring of aluminium rolling ingots. In most plants the attention of metallurgists has been directed in large part—at least so far as the ingot problem is concerned—to the production of sound, clean ingots, free from internal shrinkage cavities, gas-holes, and foreign non-metallic included matter. Not unnaturally, sound and clean ingots are highly desirable. If the original ingot contains the defects just mentioned, the finished sheets may be rejected because of clean slivers, blisters, dirt slivers, or some other cause which spoils the surface appearance.

Although highly important, not only from the point of view of properties, but also of performance in rolling, the question of crystal structure has hitherto received little attention in practice. Recent work in Germany has indicated that the control of crystal structure in aluminium rolling ingots is requisite and essential for the best results. True enough, it has been generally recognised that the control of crystal structure is important in ingots to be used for forging, and for rolling structural shapes in heat-treatable aluminium alloys. On the other hand, in the production of aluminium sheet for use in body building, general stamping, and in making "pots and pans," most operators have either ignored the question of ingot structure or considered that its control is an unnecessary refinement.

Shape of Ingots.

Ingots to be used for rolling aluminium and aluminium-alloy sheet and coil are cast in various sizes, shapes, and weights, depending on requirements and the preferences of different mill operators. The conventional ingot is a rectangular parallelepipedon, although in some plants ingots of similar shape, but bulged on the narrow sides, are used. Design of the bulged portion varies considerably.

Fig. 1 shows the shape of the typical aluminium rolling ingot. Fig. 2 shows the shape of an ingot having bulged sides, the cross-section of the bulge being U-shaped. Fig. 3 shows the shape of another ingot having bulged sides, the cross-section of the bulge being V-shaped. The first-mentioned is often referred to as the square-edge, the second as the U-edge, and the third as the V-edge ingot. Fig. 4 shows partial cross-sections of ingots, indicating some edge designs which are, or have been, used. Ingots having slight concavity in the narrow sides have also been tried. In some plants the round-edge or rounded V-edge ingot is favoured. The square-edge ingot is preferred in American practice. In some designs of tilting vertical book-moulds one edge of the ingot is square and the opposite edge is fluted or shaped as an offset V (*cf.* Fig. 4). The flute or V is cut in the pouring side of the mould, and serves as a channel for the flow of metal.

Much can be said about the shape of ingots, particularly from the point of view of crystal structure and ease of deformation, without cracking or going out of square in

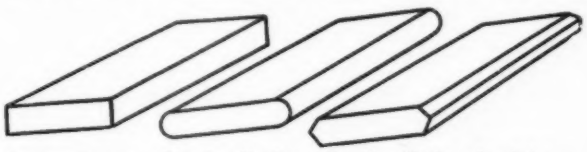


Fig. 1.—Square edge aluminium rolling ingot. *Fig. 2.—U-edge aluminium rolling ingot.* *Fig. 3.—V-edge aluminium rolling ingot.*

the hot breakdown passes, but the more theoretical aspects of these matters cannot be dealt with here. Briefly stated, one object of special shaping is to prevent the formation of highly undesirable crystal structure, or at least partly prevent the ingotism normal to the square-edge design. Another object of special shaping is to take care of the effects of deformation—a straight line cannot be deformed without stretching or bulging. The U-edge, or other round-edge ingots, are evidently better designs than the square-edge, not only as regards structure, but also in behaviour on rolling.

Sizes of Ingots.

Although rather small and very large ingots are cast, say in the range 20 to 2,000 lb., the bulk of the aluminium and aluminium-alloy sheet production is made from ingots weighing 50 to 150 lb. Ingots weighing 100 to 135 lb. are usual in American practice. A wide range of sizes is indicated in the accompanying tables.

While the size of ingot may, and must, be varied over a considerable range, depending upon the size of sheets to be rolled, most operators prefer a certain special size which has been found by experience to meet the bulk of

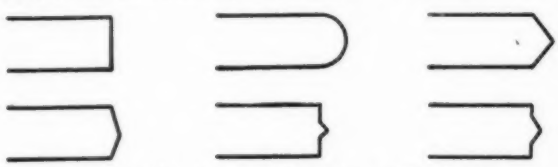


Fig. 4.—Edge designs of aluminium rolling ingots.

requirements in the most satisfactory manner. This means that when such size of ingot is used for rolling the run-of-mill production, the quantity of operating scrap (including normal and excess shearing losses, and the amount of metal turning up at the heavy-duty shear as "shorts" or averages in cutting slabs) will be at a minimum. Slab ends must, of course, either be worked into sheet or returned to the melting furnace. Many mill foremen like to have plenty of slab ends available, arguing that "some day they will come in handy to piece-out a shortage." Unfortunately, but almost invariably, when a shortage occurs, the slab ends are forgotten, or, if remembered, are found to be of the wrong size, so that additional ingots must be rolled. The occurrence of undue quantities of slab ends indicates the use of the wrong-size ingot or poor planning. Ordinarily, all slab ends should be returned promptly to the melting furnaces.

It will be obvious that, knowing the size of sheets to be rolled, the number of sheets to be obtained from each ingot (*i.e.*, the number of cuts per slab), and the scrap allowances for shearing, the size of ingot required can be calculated with mathematical nicety. It will be equally obvious that while a certain size of ingot will yield the least scrap loss (*i.e.*, the theoretical shearing allowance) for each size of the sheet, it is unpractical and unnecessary to use more than a few standard sizes. The best average size of ingot to use will necessarily vary in different mills, depending upon what sizes of sheet make up the bulk of the production. From the point of view of mill operation and capital expense for moulds, the fewer the sizes the better.

In American practice, ingots weighing from about 75 to 150 lb. are preferred for the bulk of ordinary production, although in one mill ingots weighing about 40 lb. were formerly used for coil rolling. Table 1 gives the dimensions and weights of aluminium rolling ingots which have been or are being used in American mills. The weights given are not actual but were calculated,

TABLE 1.

DIMENSIONS AND WEIGHTS OF ALUMINIUM ROLLING INGOTS, USED IN THE UNITED STATES.

Dimensions, In.			Weight, Lb.*
Thickness.	Width.	Length.	
1¾	12	18	29·0
1¾	12	18	36·9
2	12	18	42·1
2	12	20	46·8
3	12	20	70·2
4	12	17	75·7
3½	12	20	81·9
3½	12	21	86·0
4¾	12	16	88·9
3½	12	22	90·1
2¾	14	24	92·0
4	12	20	93·6
4¾	12	17	94·5
4	12	21	98·3
3½	12	24	98·3
4¾	12	18	100·0
3¾	12	23	100·9
5	12	18	105·3
4¾	12	19	105·6
3½	14	24	106·5
4¾	12	20	111·2
4	12	24	112·3
3	12	32	112·3
2¾	18	24	115·8
4¾	12	21	116·7
4¾	11¾	22	119·7
4½	12	22	122·3
4	12	27	126·4
4¾	12	23	127·8
4¾	11¾	24	130·6
4¾	12	24	133·4
4	12	30	140·4
5	18	27	236·9
7	16	24	262·1
7	16	26	283·9
7	16	30	327·6
7	16	36	393·1
7	22¼	27	410·0
7	22¼	35	531·5

* As calculated ; density of aluminium, 2·705 ; 1 cub. in. weighs about 0·0975 lb.

using the figure 2·075 grms. per c.c. for the density of aluminium (1 cub. in. weighs about 0·0975 lb.). It should be pointed out that the actual weights of aluminium ingots poured in tilting vertical book-moulds, having the cavity dimensions given in the table for the thickness, width, and length of the ingots, are normally less than the calculated weights. Thus, the actual weight may be about 2 to 6% less, due to shrinkage of the metal on freezing, blowholes, dissolved gases, and inequalities in heading. For example, the calculated weight of the 3¼-in. × 14-in. × 24-in. ingot is 106·5 lb., and the actual average weight is about 101 lb.

As illustrating the effect of ingot size on average operating scrap losses, it has been found in one mill that the loss when using the 4¾-in. × 12-in. × 24-in. ingot is about 2·5% less than when using the 4¾-in. × 12-in. × 19-in. size. In another plant experience showed that the 3¼-in. × 14-in. × 24-in. ingot was preferable to the 2¾-in. × 14-in. × 24-in. size for most operations.

TABLE 2.

DIMENSIONS AND WEIGHTS OF ALUMINIUM ROLLING INGOTS, USED IN ENGLAND.*

Dimensions, In.			Weight, Lb.
Thickness.	Width.	Length.	
Square Edge.			
¾	12	12	10·5
1½	16	20	44
2	14	17	46
2	11	21	47
2	14	24	65·2
2	14	28	76
4¾	9½	21	90
5	10	20	100
Round Edge.			
2½	13½	28	84
2½	18½	22	91
4¾	11¼	21	100
3	15¾	28	120
4¾	13½	24	143
6	15	28	234

* As given by The British Aluminium Co., Ltd.

Any ingot should be sufficiently thick, so that the original structure may be thoroughly broken up in the hot-rolling operation. In ordinary production, ingots are broken down to about ¼ in., ⅜ in., or ½ in. thick. Starting with a 4-in.-thick ingot, the respective reductions are approximately 94, 90, and 88%. These reductions are ample to destroy the ingot structure, and to develop a laminated or fibrous texture.

Table 2 shows some sizes of ingots as listed by the British Aluminium Co., Ltd. ; and Table 3 lists some sizes as given by the Vereinigte Aluminium-Werke A.-G. Three sizes of ingots used in France are given in Table 4.

Aluminium-alloy rolling ingots are cast in the same sizes and the same kinds of moulds as aluminium ingots. In the United States the bulk of the production of 3S, duralumin, and other alloys is made from ingots weighing 75 to 150 lb. When ingots require scalping, allowance is made in the thickness to provide for the metal which is to be removed. Sheets weighing 500 kg. and 800 kg. are produced from single ingots at the Vereinigte Leichtmetall-Werke G.m.b.H., Bonn, Germany. Duralumin and other alloy sheets, in various gauges, measuring 10 ft. wide by 20 ft. long, are to be rolled at the new mill of the Aluminium Co. of America, Alcoa, Tennessee. Unless suitable mechanical-handling equipment is available, it is preferable to hold the weight of single flat sheets under 250 lb., and the length under 16 ft. Coil is, of course, rolled in long lengths.

Soundness of Ingots.

As has been mentioned previously, the quality of aluminium sheet is considerably dependent on the quality of the ingots used for rolling. Great stress is laid in practice on the necessity of producing ingots free from internal shrinkage cavities, cracks, porosity, laps, and foreign non-metallic inclusions. Smooth surface faces are also desirable. In other words, sound and clean ingots free from any internal or external flaws are required. Any discontinuities in aluminium ingots—*e.g.*, blow-holes—will not weld on hot rolling as in the case of steel, but will persist throughout all the rolling operations. Ingot defects give rise to such defects in the finished sheet as inclusions, blisters, cracks, clean slivers, dirt slivers, splits, and inferior mechanical properties. Defects in sheet may be

found as surface flaws on inspection, and cause rejection solely because of appearance.

Some ingot defects are, of course, directly traceable to the melting practice. Thus, overheating causes gassing of the metal, which in turn causes porosity and blow-holes in the ingots. The effects of gassing may persist even though the metal is poured at a relatively low temperature, because liquid metals evidently do not evolve gas on cooling as readily as they absorb it on raising the temperature. Any detail of melting practice which favours the absorption of gas promotes the occurrence of unsoundness in the ingots. The rate of cooling in the moulds is also a factor affecting porosity. Quick chilling promotes soundness. With conventional ingot moulds thick ingots are more likely to be unsound than thinner ones, because the former solidify more slowly, other things being equal. Low pouring temperatures tend to promote soundness. The application of degassing methods prior to pouring is advantageous.

The occurrence of foreign non-metallic inclusions, chiefly dross particles, is associated with melting practice, improper fluxing, and methods of pouring. If aluminium is considerably overheated, there is a tendency for more

TABLE 3.

DIMENSIONS AND WEIGHTS OF ALUMINIUM ROLLING INGOTS, USED IN GERMANY.*

Dimensions, Mm.			Weight, Kg.
Thickness.	Width.	Length.	
32	300	470	12
50	220	525	15·5
60	220	525	17·8
57	305	610	25
50	370	500	25
120	220	525	37
89	305	610	44
120	355	660	75
100	350	750	75
100	475	800	100
120	500	800	125
120	600	800	150
140	600	800	175
150	545	920	200
140	680	800	200
180	660	800	250
140	850	800	250
175	800	800	300
170	1,000	800	350
180	600	1,200	350
180	700	1,200	400
180	1,050	800	400
180	790	1,200	450
180	875	1,200	500
180	1,050	1,200	600
180	1,200	1,225	700
180	1,200	1,400	800
180	1,200	1,575	900
180	1,200	1,750	1,000

* As given by the Vereinigte Aluminium-Werke A.-G.

TABLE 4.

DIMENSIONS AND WEIGHTS OF ALUMINIUM ROLLING INGOTS, USED IN FRANCE.*

Dimensions, Mm.			Weight, Kg.
Thickness.	Width.	Length.	
40	350	700	27
55	560	660	55
80	550	650	80

* As given by Grard.

aluminium oxide to be introduced into the melt than when heated to the normal temperature. However, increasing the temperature has the effect of increasing the fluidity. This favours the separation of the oxide from the melt, particles rising or sinking depending on their size and other factors. When a large proportion of light scrap is carried in the melting charge, the melt is more likely to contain suspended oxide than when pig metal and heavy scrap are used. Given good melting practice, and the application of gas-treatment and settling processes, the bulk of the suspended oxide may be eliminated. Fluxing in the pouring ladle may be required to remove oxide carried in from the bottom of the furnace on tapping, or particles from the dough-ball.

Internal shrinkage cavities are caused largely by failure to control the process of freezing—*i.e.*, the failure to feed properly. Such cavities are invariably found in ingots cast in flat (horizontal) open moulds, which are not fed. Shrinkage cavities may be found in the body of ingots cast in tilting vertical book-moulds if the pouring rate is too fast or the solidification too rapid. Cavities may also be found in the head-end of ingots similarly cast, if the heading is not carried out properly. Internal cracks are associated chiefly with the crystal structure of the ingot, and, consequently, with the mould design, cooling rates, and pouring methods. Surface cracks may be associated with the condition of the mould surface, composition of the metal, and hanging in the mould. Internal cracks may often be eliminated with difficulty, but the occurrence of external cracks may ordinarily be overcome.

Crystal Structure of Ingots.

Most metallurgists have believed, and recent work has tended to prove broadly, that the most desirable macrostructure in a rolling ingot is one consisting entirely of small equiaxed crystals, the presence of columnar, or stalk-like, crystals being undesirable. When columnar crystals are present it has been shown that, so far as ease of deformation is concerned, they have the most favourable position when their long axes are parallel to the direction of the rolling plane, and the most unfavourable position at right angles to that plane. Ingots containing masses of columnar and equiaxed crystals, or consisting largely of columnar crystals, are more likely to crack in the breakdown operation than ingots consisting solely of equiaxed crystals. As ordinarily produced in conventional vertical chill moulds, the macrostructure of aluminium rolling ingots shows a greater or lesser quantity of columnar crystals, the long axes of which are, unfortunately, perpendicular to the plane of rolling. A minor quantity of columnar crystals having their long axes parallel to the plane of rolling may be present. These are situated at the bottom of the ingot.

Although the macrostructure may vary greatly, depending upon various factors, a cross-section cut through the centre of the ingot at right angles to the plane of the length may show the following features, viz., (1) a thin rim of small equiaxed crystals, formed against the walls of the mould ; (2) adjoining this rim a zone of columnar crystals, extending toward the interior of the ingot from all wall faces ; and (3) in the centre section, an area of fairly large equiaxed crystals. It will be understood that the boundary rim of small equiaxed crystals may be practically absent. Also, the columnar crystals may occupy the bulk of the section, having grown out from the mould faces and met in the centre of the ingot.

The various factors affecting ingot structure, particularly as regards non-ferrous metals (brasses), have been discussed by Genders,[8, 25] among others. Commercial 99+% aluminium, unfortunately, tends to form columnar crystals very readily—because of the high thermal conductivity and the very short freezing range. Broadly speaking, fast chilling promotes the formation of equaixed crystals, and a slow solidification rate is conducive to the formation of columnar crystals. A low pouring temperature promotes the formation of equiaxed crystals. In ordinary cast-iron chill moulds, the mass of the mould and its temperature are important factors affecting structure. Columnar crystals tend to form with a high pouring temperature and a low mould temperature, and, conversely, the combination of a low pouring temperature and a high mould temperature favours the formation of equiaxed crystals. A steep temperature gradient between the mould walls and the

liquid metal in the interior promotes the formation of columnar crystals. Genders[8] found that a very slow rate of pouring and extremely rapid pouring (almost instantaneous filling of the mould) promoted columnar crystallisation under certain conditions in casting thin brass ingots: an intermediate rate reduced the length of the columnar crystals and increased the area of the equiaxed crystals. Genders[25] also found that turbulence as caused by gases evolved from mould dressings inhibits columnar crystallisation. The long solidification range of some alloys, in contrast with the instantaneous freezing of pure metals, favours the formation of equiaxed crystals.

Referring to the effect of the ingot structure on the behaviour of aluminium on rolling, this matter has been studied by Seidl and Schiebold[7]. Among other things, they find that the columnar and equiaxed crystals behave differently during the formation of the rolling texture. Briefly stated, the columnar crystals, having their axes parallel to the rolling plane, attain the rolling texture most easily and completely; similar crystals having their axes at right angles to the plane are unsatisfactory in this respect. The latter exhibit much greater resistance to deformation than the former. Seidl and Schiebold have shown that material of better mechanical properties can be obtained by rolling ingots having proper structure, as compared with the ordinary cast material. In an examination of columnar crystals of various metals for orientation in regard to direction of solidification, Nix and Schmid[20] found that aluminium gave a simple fibre texture with the (100) direction parallel to the length axis of the columnar grain.

Columnar crystallisation gives rise to zones of weakness, as has been pointed out by Aitchison[3] in the case of steel ingots. These zones may include the following: (1) The juncture of each columnar crystal with its neighbours; (2) the juncture of sets of columnar crystals; and (3) the juncture of a set of columnar crystals with a set of equiaxed crystals. Cracks may exist at the juncture of two sets of columnar crystals, and foreign inclusions may be found at such places. Planes of weakness formed by columnar crystallisation may give rise to cracking and lamination on rolling. Also, columnar crystals starting from the surface, or exposed by scalping, are likely to separate on rolling, and hence cause surface cracks or at least roughness.

Segregation of Ingots.

Ingots cast in 99+% aluminium, as well as the various rolling alloys, exhibit the typical heterogeneity, common to other alloys, known as inverse segregation. The effect is more noticeable and more serious in its practical consequences in the case of duralumin than with ingots of 99+% aluminium. The phenomenon of inverse segregation in extreme cases is exhibited visually as an exudation of portions of the mass of metal from the surface, the exuded portions appearing as large, globular masses in the case of intermediate alloys of aluminium, or as small beads or droplets in the case of some light alloys. Chemical analysis of the exuded matter has shown that it is enriched in alloying metals with respect to the average composition of the melt. In the case of rolling ingots in light alloys cast by the ordinary methods, the inverse segregation may appear merely as a roughening of the surface (the exuded beads being of microscopic size, or at least very small), or simply as an enrichment of the surface layers. When not exhibited visually, the phenomenon may be detected by chemical analysis and in some cases by microscopic examination.

The general question of inverse segregation in alloy ingots has been discussed by Genders,[14] among others. Although all the factors affecting the mechanism of the phenomenon are not thoroughly understood, it is known that inverse segregation is influenced by the pouring temperature, the thermal gradient existing between the exterior and interior portions of the metal in the ingot mould, composition of the alloy, contraction on freezing, the presence of dissolved gases in the alloy, and the internal pressure in the mass of metal. A high pouring temperature promotes inverse segregation, as does a steep thermal gradient between the exterior and interior of the metal in the mould. Exudation or surface enrichment is more pronounced in alloys like duralumin, having a fair range of temperature between the liquidus and the solidus than in commercially pure aluminium, which has a very short freezing range. Pressure is influenced by contraction and the presence of dissolved gases. Genders[14] found that in extreme cases of inverse segregation, exudation at the surface was accompanied by the escape of dissolved gases.

In the case of the heat-treatable aluminium alloys, the subject has been studied by Woronoff[21] and Schwerber[24]. Experiments have shown that the phenomenon can be counteracted in light alloys by reducing the amount of elements which induce inverse segregation, by diminishing the variation in freezing rates of the exterior surface layers, and of the interior mass of metal (*e.g.*, by heating the mould), and by choice of proper relation between the size of mould and size of ingot. In short, inverse segregation is minimised by suitable control of the solidification rate.

The presence of the enriched surface layer in aluminium-alloy ingots gives rise to difficulties in rolling, principally cracking. In practice it is customary to remove the rough or segregated surface layers of aluminium alloy (duralumin) ingots by scalping—*i.e.*, by machining with a miller or shaping tool to a depth of about $\frac{1}{4}$ in. or more, or less, depending on the condition of the surface and the behaviour in rolling. Ordinarily, the ingot is scalped on all faces, or at least on the largest faces, before the hot breakdown operation, but in some cases it is given a few passes and then scalped. Commercially pure aluminium, 3S, and some alloys do not require scalping, but this treatment is essential in the case of duralumin and related alloys. The pre-treatment of ingots before hot rolling is discussed in a subsequent article of this series.

SELECTED BIBLIOGRAPHY.

1 R. J. Anderson, "Blowholes, Porosity, and Unsoundness in Aluminium-alloy Castings," U.S. Bureau of Mines Tech. paper 241, 1919, 31 pp.
2 R. J. Anderson and M. B. Anderson, "Aluminium Rolling-mill Practice," *Chem. and Met. Eng.*, vol. 22, 1920, pp. 545-550.
3 L. Aitchison, "Zone of Weakness in Solidified Ingots," *Chem. and Met. Eng.*, vol. 23, 1920, p. 280.
4 R. J. Anderson, "Cracks in Aluminium-alloy Castings," *Trans. Amer. Inst. of Min. and Met. Engrs.*, vol. 68, 1922, pp. 853-860.
5 R. J. Anderson, "Inclusions in Aluminium-alloy Sand Castings," U.S. Bureau of Mines Tech. paper 290, 1922, 25 pp.
6 Anon., "Aluminium and Its Alloys. II.—The Working of Aluminium," *The Metal Ind. (London)*, vol. 25, 1924, pp. 421-422.
7 E. Seidl and E. Schiebold, "Das Verhalten inhomogener Aluminium-Gussblöckchen beim Kaltwalzen," *Zeit. fur Metallkunde*, vol. 17, 1925, pp. 221-226; 283-288; 320-328; 365-368.
8 R. Genders, "The Interpretation of the Macrostructure of Cast Metals," *Jour. Inst. of Metals*, vol. 35, 1926, pp. 259-279.
9 G. Masing and O. Dahl, "Über die Erstarrung von eisenhaltigen Aluminium," *Wissen. Veroff. Siemens-Konzern*, vol. 5, 1926, pp. 152-159.
10 E. Seidl, "Influence of Chemical and Crystallographic Properties of Casting Metal on Behaviour During Rolling," *Min. and Met.*, vol. 8, 1927, pp. 454-460.
11 W. Rohn, "Wassergekühltekokillen," *Zeit. fur Metallkunde*, vol. 19, 1927, pp. 475-478.
12 F. von Goler and G. Sachs, "Zur Entstehung des Gussgefügen," *Zeit. des Vereines deutsch. Ingen.*, vol. 71, 1927, pp. 1,353-1,357.
13 P. Schwerber, "Das Giessen von Schmiedbaren vergütbaren Aluminiumlegierungen," *Metall-Technik*, vol. 52, 1927, pp. 409-412.
14 R. Genders, "The Mechanism of Inverse Segregation in Alloys," *Jour. Inst. of Metals*, vol. 37, 1927, pp. 241-270.
15 M. L. V. Gayler, "The Under-cooling of Some Aluminium Alloys," *Jour. Inst. of Metals*, vol. 38, 1927, pp. 157-184.
16 F. Gadenheuer, "Der Einfluss der Kokille und der Desoxydation auf die Kristallisation ruhig erstarrender Blöcke," *Stahl und Eisen*, vol. 48, 1928, pp. 713-718; 762-766.
17 W. A. C. Newman, "Strip Casting," *Foundry Trade Jour.*, vol. 38, 1928, pp. 3-6
18 G. Tammann, "Die Entstehung der Gusstruktur," *Zeit. fur Metallkunde*, vol. 21, 1929, pp. 277-282.
19 G. Masing, "Technische Probleme bei der Erstarrung der Metalle," *Zeit. fur Metallkunde*, vol. 21, 1929, pp. 282-285.
20 F. C. Nix and E. Schmid, "Über die Gusstrucktur von Metallen und Legierungen," *Zeit. fur Metallkunde*, vol. 21, 1929, pp. 286-292.
21 S. M. Woronoff, "Zur umgekehrten Blockseigerung beim Duralumin," *Zeit. fur Metallkunde*, vol. 21, 1929, pp. 310-316.
22 A. Glazunov, "Crystalline Grains in Castings," *Foundry Trade Jour.*, vol. 41 1929, pp. 117-120; 131-134.
23 W. J. P. Rohn, "The Reduction of Shrinkage Cavities and Vacuum Melting," *Jour. Inst. of Metals*, vol. 42, 1929, pp. 203-214.
24 P. Schwerber, "Das Giessen von Walzblöcken aus vergütbaren Aluminium-Legierungen," *Giesserei-Zeitung*, vol. 27, 1930, pp. 61-67.
25 R. Genders, "Macrostructure of Cast Alloys: Effect of Turbulence Due to Gasses," *Jour. Inst. of Metals*, vol. 43, 1930, pp. 187-192.
26 M. L. V. Gayler, "A Study of the Relation Between Macro- and Microstructure in Some Non-ferrour Alloys, paper before Inst. of Metals, Southampton meeting, Sept., 1930.

The types of moulds used for pouring aluminium rolling ingots will be discussed in the next article of this series.

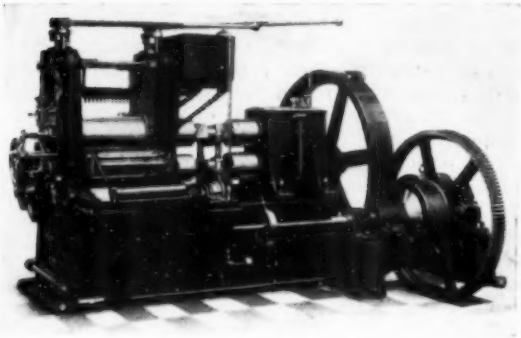


Fig. 2.—Typical Intermediate Mill.

ROLLING—— METAL FOIL

By

C. E. Davies, A.M.I.Mech.E.

TIN foil, which may be nearly pure tin with some addition of antimony, is generally preferred for wrapping articles of food; and composition foil in alloys of lead and tin is largely used for packing tobacco and other materials, whilst lead foil is required for tea-chest linings. This tea lead may be coated with tin, the coating being applied in the rolling process, lead slabs being rolled between two thin sheets of tin, the whole being welded together by the pressure of the rolls, so that when the combined metals are reduced to foil thickness the resulting sheet of lead is covered on both sides by a thin coating of tin.

Tin, lead, and tin-lead alloys, owing to their plastic nature, are especially suitable for cold rolling to an extremely fine thickness, and as tin is a relatively expensive metal, it is necessary for economy to produce tin foil as thin as is possible to obtain it, and it is remarkable that this foil is regularly produced by rolling in sheets as thin as 0·00025 in.

Lead and composition foils are more commonly thicker, but even these are commercially produced in a thickness of 0·001 in.

The advantage of tin and lead and alloys of these metals for rolling to such extreme fineness is that they have little or no tendency to harden by cold working, and that annealing is unnecessary. It is, therefore, possible to cold roll from cast slabs 1 in. thick and thicker, down to the finished foil without any heat-treatment.

Aluminium, which can now be rolled to the same thickness and finished so as to be practically as flexible as the softer metals, offers greater difficulties in the rolling process owing to the hardening of the metal by cold working, and heat-treatment is necessary several times in the course of the rolling process to restore its ductility and to render it suitable for further reduction in thickness, and also to give the necessary flexibility to the finished product. Generally, whilst lead and tin can be cold-rolled from cast ingots to the finished foil, the rolling of aluminium foil may be said to start from strip of a suitable thickness, which has been previously rolled in regular strip mills.

The rolling of the softer metals is particularly interesting as a special case of cold rolling, and although the process is similar in essentials to the rolling of the harder metals and alloys, such as copper, brass, steel, etc., there are important differences due to the fact that tin and lead have a more truly plastic nature, with the result that there is a marked extrusion effect and the metal flows very freely under the pressure of the rolls. The old method of producing very thin lead and tin foil was similar to that employed in the rolling of thin steel sheets—that is to say, after rolling as thin as was possible in a single thickness, the sheets were further rolled in packs, but the method and mills available were only able to produce single sheets of foil of a relatively small area, and the pack or "book" rolling process was slow and costly.

A great advance has been made and foil is now produced in considerable width in continuous coils, which are wound on spools direct from the rolls, these coils of wide foil being afterwards slit into narrower bands from which smaller squares and sheets, as required by the user, can be cut.

The rolling of strip metal as thin as 0·00025 in. in a width of from 15 in. to 20 in. wide in a continuous unbroken coil weighing about 100 lb. is a remarkable achievement, and required the development of special rolling machinery and rolling technique.

Foil rolling in continuous coils was developed in Germany, from whence it was introduced into England together with rolling mills and other machinery specially designed for the work. Since then, many improvements in machinery and methods have been introduced, and foil rolling mills of the most up-to-date type are regularly built in this country, notably by Messrs. W. H. A. Robertson and Co., Ltd., of Bedford. Taking the production of tin foil in the lightest gauges, there are three stages in the rolling process.

Breaking Down.—Ingots are cast approximately 1 in. thick, and of sufficient width to give the desired width of foil, in C.I. moulds. These ingots are rolled in the direction of their length in powerful breaking-down mills, having rolls about 12 in. diameter, 20 in. to 24 in. long, depending on width of foil required. In this mill the metal is reduced to such a thickness that it can be coiled on spools, ready for feeding into smaller intermediate mills.

Generally, the ingot is reduced to about 0·012 in. thick in a series of seven or eight passes in the breaking-down rolls, and the metal is coiled as soon as it is thin enough.

Fig. 1.—Typical Breaking-down Mill.

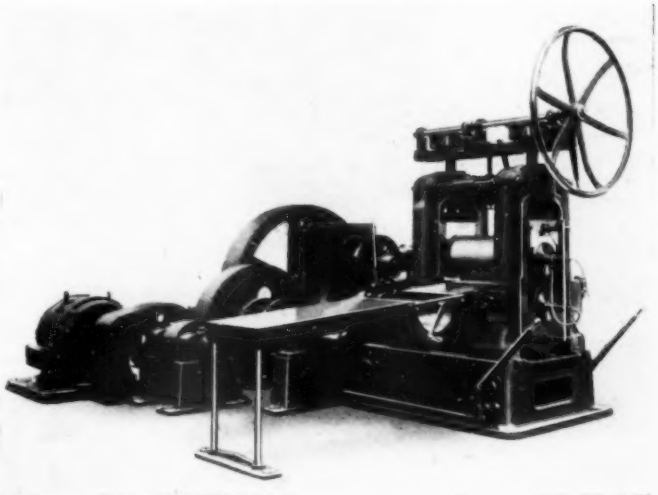


Fig. 1 illustrates a typical breaking-down mill made by Messrs. W. H. A. Robertson and Co., Ltd. The rolls are 12 in. diameter, 20 in. or 24 in. face width, are of chrome steel, hardened and ground to a slight camber—*i.e.*, the rolls are finished somewhat larger in diameter at the centre than at the ends. The upper roll is adjusted by steel screws operated by handwheel at side through machine-cut gearing.

The usual pinion housing of the enclosed type is fitted with machine-cut double helical tooth pinions, from which the rolls are driven through coupling spindles and couplings of the regular type. The lower pinion is directly driven

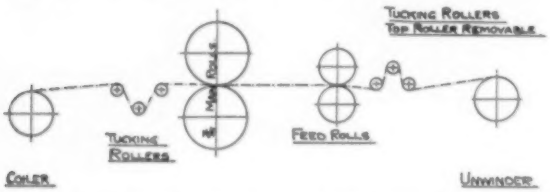


Fig. 3.—Typical Arrangement of Mill and Equipment.

through suitable reduction gearing from an electric motor of 80/100 h.p. Special guide equipment at entry side of rolls is provided, and at the outlet a powerful coiling or winding gear is fitted; the coiling spindle, on which removable metal spools or drums are mounted, is driven at the correct speed through gearing from the mill driving shaft. This drive is transmitted through a friction clutch, with micrometer adjustment to regulate the coiling tension, and to compensate for increasing diameter of coil.

After the metal has once been coiled, it is kept on its spool, which is removed bodily and fitted to an unwinding spindle, with adjustable brake, at entry side of rolls, for further reduction. Usually the metal is coiled after the first three or four passes.

A main friction clutch is included in the mill driving gear for stopping and starting the rolls. This clutch is, however, frequently omitted in the latest design, and the rolls are stopped and started by direct electric control of motor, by means of convenient "push-button" switches which are mounted on the roll frames.

Intermediate Mill.—The spools of rolled metal from the breaking-down mill are next rolled in smaller mills having rolls 9 in. to 10 in. diameter, 18 in. to 22 in. face, which are also of hardened steel, ground with the greatest accuracy to a camber, and it is at this stage that the special difficulties to be encountered in foil rolling are met. The strip is already thin, and the modern intermediate mill—an example of which is shown by Fig. 2—is designed to reduce this metal to one-thirtieth of its thickness in one pass, the resulting thickness being generally about 0·001 in. As will be understood, the handling of such thin strip in a metal having a comparatively low tensile strength requires great care and special equipment, not only to avoid tearing the foil as it issues from the rolls, but to ensure exact uniformity of thickness over the width.

The essential principle to be observed is that the strip must be positively controlled from the point of leaving the coil on the unwinder, at the inlet side of mill, until it is wound on the coiling drum at the outlet. Moreover, the speed at which the thick metal enters the rolls must also be regulated to suit the reduction ratio required. This regulation of feed speed is quite a special feature of this type of foil mill, as, without this, the metal would be drawn in by the rolls at a greater rate than is required, and the resulting thickness would be much greater than required, besides which, the metal would be buckled and torn in the process.

This control of the metal is obtained by means of an adjustable brake on the unwinding spindle carrying the spool of metal to be rolled, which regulates the tension on the strip as it enters the rolls; a series of staggered guide rollers over which the metal passes and is thereby kept flat and straight, and a pair of feed rollers which are driven by gearing at the correct speed in relation to the speed of the main rolls, and the ratio of elongation due to the reduction in thickness. With this equipment a very great reduction in thickness in one pass through the rolls can easily be effected, generally from one-twelfth to one-twentieth of its entering thickness, and frequently strip is reduced from 0·03 in. thick to 0·001 in. in one run through the mill, in elongation of 30 to 1.

The illustration, Fig. 3, shows a typical arrangement of the mill and accessory equipment, and the run of the metal through the mill. As will be understood, the speed of the strip through the feed rolls before entering the main rolls will be about one-fifteenth of the speed through the latter, and owing to the extrusion effect resulting from the pressure of the main rolls, the foil leaves at a speed very considerably in excess of the peripheral speed of these. Consequently the speed of the winding spool must be adjusted by means of a very sensitive friction clutch to give just sufficient tension to draw the metal flat and taut, without exceeding the strength of the foil and cause it to break. As will be understood, with such soft metal only about $\frac{1}{1250}$ in. thick, these adjustments must be very fine.

Many thicker foils, especially in lead or tin lead composition, can be finished outright on this mill, but the very fine tin foils which are required one-third and one-fourth of the thickness require further rolling, and this extreme thinness cannot be successfully accomplished by rolling in a single thickness. Consequently, a number of coils, usually four, can be rolled together and the total thickness reduced to such an extent that the desired finished thickness for each single strip is obtained.

Finishing and Polishing Mills.—For this work special mills are required, as shown by illustration in Fig. 4. The size of the rolls and the general design is similar to the intermediate mill described above, but the feed rolls are

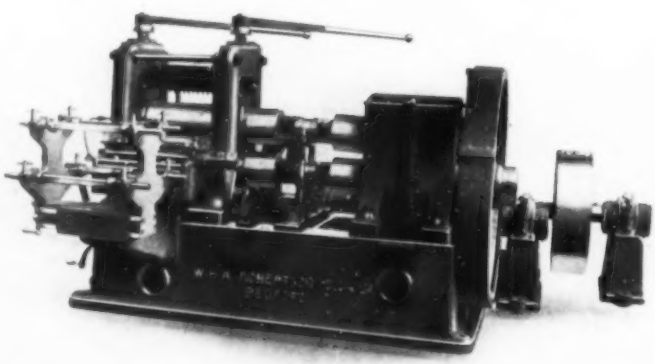


Fig. 4.—Finishing and Polishing Mill.

omitted and are unnecessary, and an adjustable unwinding spindle stand is fitted at the inlet side, so that four single spools may be mounted simultaneously, each provided with an adjustable brake to regulate the tension; from these the four strips are lead over a series of guide rollers running very freely in ball bearings through the main rolls, and thence to a coiling spool, on which the four strips are wound together as one coil.

As will be understood, owing to the fact that only one side of the two outer strips come into contact with the rolls, the inner six strip faces are not subjected to the burnishing effect of the rolls, and as one side of each strip of foil is

required to be bright and polished, it is necessary to reverse the relative positions and to provide for a further rolling or polishing pass. This work is done on mills similar to those described above. Special unwinding and rewinding machines are employed in this connection, together with cutting or slitting machines for cutting the wide coils into narrower bands as required by the users. The run of the metal through a mill rolling four thicknesses is shown in outline by Fig. 5. Usually, fine slitting cutters are fitted on the mill itself to trim off the rough edges of the foil. With both intermediate and finishing mills the accurate grinding and polishing of the rolls is of the greatest importance. As

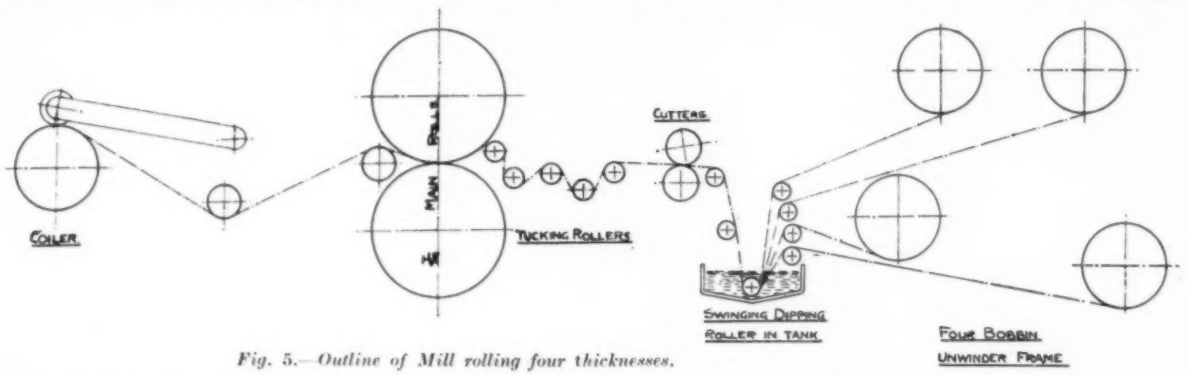


Fig. 5.—Outline of Mill rolling four thicknesses.

will be understood, when rolling metal to a thickness of $\frac{1}{1000}$ in. or less, the slightest irregularity in the roll surface would completely destroy the foil, and would render successful rolling quite impossible. This accuracy is more difficult to secure owing to the necessity for the rolls to be ground to a *camber*—that is to say, the rolls must be slightly larger in diameter at centre than at ends to allow for flexure of the rolls under pressure and to facilitate the even flow of the metal.

The amount of camber or fullness of the roll at centre varies with the nature of metal or alloy rolled, also with the finished thickness required. Generally the camber measured on *the diameter* will vary from 0·001 in. to 0·004 in., and to grind the roll barrels 18 in. to 22 in. long with a perfectly smooth curve from end to end requires a very accurate grinding machine and considerable skill on the part of the operator. With a total camber of, say, 0·002 in., variation of only 0·0002 in. in any part of the roll, means in proportion a very serious error, amounting as it does to $\frac{1}{10}$ in. of the total camber. Moreover, in spite of the greatest care in roll grinding, owing to the fact that with these fine mills there are differences in the structure of individual rolls, and also a difference between a newly finished roll and one that has had previous service, the determination of the correct camber for any particular work is very difficult, and final adjustment can only be obtained by trial rolling, and with the guidance of special experience.

Uniform hardness of roll surface is also an important factor in successful foil rolling. Generally, a hardness as measured by Shore scelerescope from 95° to 105° is satisfactory, but this hardness must be very uniform over the whole of the barrel surface. The pressure exerted by the rolls on one another, and consequently on the intervening metal, is very considerable, and before the metal is entered in finishing or intermediate rolls, the top roll adjusting screws must be hard down on the bearings, so that the cambered roll is initially bent practically flat on the contact side. For this reason mills of this type are provided with specially heavy long spanners, not only to facilitate the initial application of roll pressure, but to provide for fine adjustment on one end of the roll or the other *during rolling*. The experienced operator can correct any "ripple" or "frilled" effect shown on the foil delivered from the mill by adjusting one or other, or both, of the pressure screws.

This adjustment, together with the regulation of the brake or coiler tension is the most important duty in the operation of a foil mill. Some measurements have been taken of the roll pressure required for reducing and finishing foil, which show that the pressure on each bearing is from 20 to 30 tons, giving a total roll pressure of 40 to 60 tons.

To withstand these heavy loads, the roll frames or housings for mills of this type are invariably made as steel castings; also the bearing pressures on the roll necks may be 1,500 lb. per sq. in. or more; satisfactory lubrication of these bearings is, therefore, difficult to provide and excessive heating of bearings and roll necks is a frequent trouble. With the most modern mills, roll bearings are internally water cooled, and are lubricated by automatic pressure-feed mechanical lubricators.

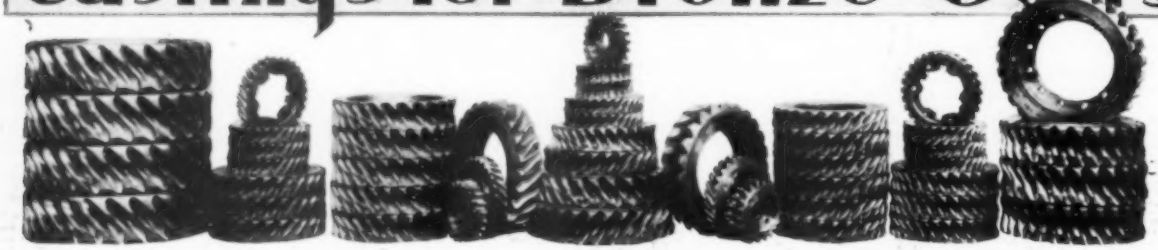
A certain amount of heating of the rolls in a foil mill is not objectionable, in fact it is to some extent advantageous, but it is important to keep the roll temperature as near uniform and constant as is possible. Most alloys of lead will roll more easily if the metal is warm, and it is even considered desirable that the building in which foil finishing mills are working should be maintained at a constant temperature of about 70° F. Extreme variation in temperature of the metal and the rolls is very detrimental to the rolling of thin foil, and very cold metal loses, to a great extent, its ductility. It is also necessary to provide suitable and ample lubrication of metal and rolls when finishing foil, and mills, both of the intermediate and finishing types described in the foregoing, must be equipped with a system of spray pipes, etc., for running a lubricant on to both top and bottom rolls and on to both sides of the metal as it enters the rolls.

In the case of the mill illustrated by Fig. 2, a rotary pump is fitted on the mill itself, which draws the lubricant from a tank contained in the mill and pumps the liquid to an upper tank, from which it flows by gravity through a properly arranged pipe system to the various roll and metal sprays. In the case of the upper roll, a long trough is fitted above the roll, which is provided with a number of small cocks, arranged at every inch or so along the length of the roll, so that the supply of lubricant can be regulated independently to any part of the roll length. This provides the operator with another means of controlling the rolling of the metal, as an increase or decrease of lubricant supply to any part of the roll will accelerate or retard the flow of the metal. Great care must be taken to keep rolls in all foil mills absolutely free from grease, and the lubricant used for tin and lead foil is generally a soap solution or soluble oil.

For other mills, such as that illustrated by Fig. 4, the lubricant supply is obtained from a central system which is common to several mills, the liquid after use being drained into a sump, from which it is pumped to a tank fitted at a high level for gravity feed to all mills in the building. Breaking-down mills do not require lubricant, the metal being rolled dry, but the rolls in such mills must be very carefully cleaned and free from grease. Aluminium foil is rolled from coils of strip in mills similar to that shown by Fig. 4, with modification in detail. For this metal a different lubricant to that used for tin and lead is required.

(To be continued.)

Castings for Bronze Gears



Part II.

* By Francis W. Rowe, B.Sc., M.I.M.M.

Bronze gear castings, produced by ordinary methods, are apt to be variable. Low coefficient of friction and maximum resistance to wear are the primary requirements of bronze for this work.

So diverse and complex are the stresses to which a bronze gear is subject in service, that great care is necessary in assessing the relative values of the various attributes of a material. The purchaser, or even the metallurgist without specialised experience, is often prone to over emphasise particular features of a bronze which have probably been obtained at the expense of other at least equally valuable characteristics. For instance, most specifications covering bronze for gears give analysis, tensile strength, and elongation. It is easily possible to produce a bronze satisfying these three requirements, and yet being infinitely less suitable for gearing than another bronze which, whilst still meeting the specification, has not done so by robbing itself of other valuable properties.

Long experience has shown that the most valuable feature to be aimed for in producing bronze castings for gears is consistency. Castings produced by ordinary methods, whether they be of iron, steel, or non-ferrous alloys, are notoriously apt to be variable, due to the number of variables entering into foundry practice.

The breakage or premature wearing out of a bronze worm-wheel, particularly in a heavy vehicle, is a matter of serious moment for the owners of the vehicle. The total cost of repairs, towage cost, etc., is from twice to six times the value of the worm-wheel, and thus any extra cost entailed in manufacture, due to closer methods of control, purer raw materials, and more rigid testing and inspection, is usually compensated by much greater freedom from service troubles. Unfortunately, the user is often not sufficiently aware of the dangers of making or purchasing gears and gear castings to conform merely to such loose specifications as are now existent, and many of the troubles with bronze gears in service are attributable to unsuitable or poor material.

Coefficient of Friction.

The primary requirement of a bronze for worm-wheels and other gears is that it shall run with the lowest coefficient of friction, and with the minimum amount of wear.

Low coefficient of friction means, of course, high efficiency and cool running in service. This is an attribute of considerable moment, particularly with such work as high-speed coach drives. Naturally, the amount of oil furnished for lubrication is limited by the size of back axle pan. This cannot be made larger than is absolutely necessary on account of such factors as ground clearance and low loading. Even now, in the modern high-speed coach, the back axle pan often protrudes through the floor of the vehicle, and every quarter of an inch in the diameter of the worm-wheel and the diameter of the housing is a matter of great importance.

**Chief Metallurgist, David Brown & Sons (Huddersfield) Ltd.*

Troubles start in various directions if the oil temperature exceeds 80° C. The lubrication value of the oil rapidly falls away and rapid wear and even breakage of the wheel, and softening of the worm due to high temperatures localised at the point of contact of the gears, may occur.

Of the various materials tried from time to time for worm-gears, only the tin or tin-phosphorus bronze has been found universally suitable for the heaviest duties. Whilst materials can be found with lower coefficients of friction—*e.g.*, the leaded bronzes and the white metals—their physical characteristics in other directions are such as to preclude their general application.

The copper-aluminium alloys (so-called aluminium bronzes) were perhaps the only serious rival the bronzes had for this duty, but their higher coefficient of friction and absence of "bearing structure" rendered them unsuitable for heavily loaded gears, where their undoubted superiority in strength would have made them most valuable.

Probably the most extensive use of aluminium bronze worm-wheels was for the Ford 1-ton truck, where, due to the particular design, a generous size of worm-wheel was permissible. On the whole, aluminium bronze gave excellent service in this particular truck, but for various reasons this model has now adopted another form of final drive. Ford's however, have always used, and still use, phosphor-bronze for their more heavily stressed tractor worm-wheels.

Resistance to Wear.

Resistance to wear is in some aspects correlated with coefficient of friction, but not altogether so. Our ideas on

Fig. 5.—Typical pitting in sand-cast bronze worm wheel

the subject of resistance to wear, either in ferrous or non-ferrous materials, have not yet crystallised, and much

further work remains to be done before one can dogmatise on this very intricate matter.

In bronzes, however, the greatest wear appears to take place, logically enough, where the density is low, indicative of loose packing of the crystals. Such material, whilst possessing a low coefficient of friction (helped, no doubt, by the microscopic oil pockets furnished by intercrystalline voids, is subject to surface attrition by the worm, and the loosely tied particles fall away. Such material also suffers badly from "pitting," as distinct from pure wear.

Fig. 6.—Cracks in bronze worm wheel due to bronze of too great brittleness.

The wear, *per se*, is also largely influenced by the amount of alpha delta eutectoid present. This constituent should form as large a portion of the microstructure as is possible without endangering the tensile strength and resistance to shock. This is achieved by having from 10 to 13% tin present, dependent on the design of wheel, mode of casting, and the other constituents. The tin content permissible or desirable depends largely on the amount of phosphorus present.

Pitting.—Pitting of gears is a common form of failure or partial failure in all types of gears. Formerly, it was a phenomenon invested with much mystery, but recent research work has cleared up a great deal of this. Pitting in all gears is a fatigue failure induced by excessive surface loads, resulting in higher compressive and reversed shear stresses than the material is capable of standing. The indirect causes may either be localised concentration of stress due to inaccurate cutting or mounting or deflection under load, or simply low fatigue strength of the materials.

The characteristics of pitting are the same whatever the material—that is, small patches of the material varying from $\frac{1}{16}$ in. diameter to $\frac{1}{2}$ in. diameter, or even more fall out of the face of the gear, giving an appearance similar to that in Fig. 5. Actually, with the most usual types of loading, the point of maximum concentration of stress is some distance below the surface of the tooth, and thus rupture takes place first at a distance below the surface dependent on the degree of overstress, and the crack gradually spreads to the surface, when the piece falls out.

The remedy for gears which pit, is either to alter the contact so that the load is evenly distributed over the whole face width, or to increase the fatigue strength of the material, or to decrease the loading by altering the pitch, size, or shape of the gears.

Tensile Strength and Yield Point.—Whilst there is no great need for an extraordinarily high tensile strength or very high yield in tensile in bronze for worm gears, yet a certain fixed minimum must be obtained if full advantage of the limits of surface stress which the bronze will carry is to be obtained. The actual tensile strength in the rim of a worm-wheel casting for the heaviest duties should not in any case fall below 15 or 16 tons per sq. in., and should preferably have a margin of several tons above this. If there is a likelihood of the strength falling below this, then the rim section has to be increased and the maximum stress suitably diminished below that which a good bronze will stand.

Resistance to Shock.—It is highly essential that a worm-wheel bronze should have a reasonable freedom from brittleness, and this is one feature which limits the permissible tin and phosphorus content with many designs of wheels. Due to the large amount of alpha delta eutectoid present, all high tin bronzes are relatively brittle as compared with such materials as steel or the solid-solution non-ferrous alloys, such as manganese "bronze" or aluminium "bronze."

The usual method of testing for brittleness in this country is by the Izod impact test. Whilst, strictly speaking, the test measures only the resistance of the material to the propagation of a crack, the notch approximates closely to the conditions obtaining in a gear-wheel. A worm-wheel should not be subject to an inordinate amount of shock load, but the manner in which the stresses are imposed often approaches those of pure impact, and materials which are excessively brittle very quickly fail, usually in a manner similar to that shown in Fig. 6.

Slackness or backlash in various parts of the transmission, a fierce clutch or a driver who races his engine and bangs in his clutch are all likely sources of heavy shock load, and the bronze must be capable, given a reasonably good design, of successfully withstanding these.

The standard B.E.S.A. Izod impact piece is one 10 mm. square, with a 45° notch 2 mm. deep, with a radius of 0·25 mm. at the bottom. This size of bar, however, with ordinary bronzes, does not give a sufficiently large reading to differentiate sufficiently between the varying compositions and various methods of casting, and the author has for a number of years used a bar 20 mm. × 20 mm. with the standard notch for cast bronzes. Such a bar gives readings of from 5 to 80 ft.-lb., dependent on the analysis structure.

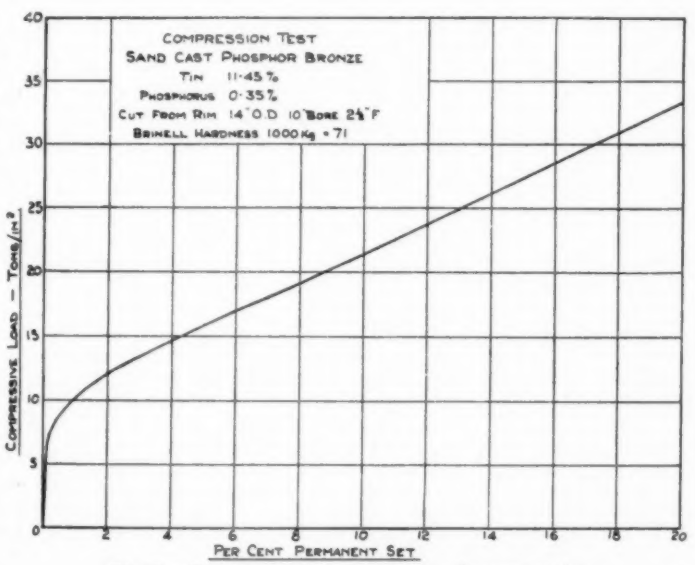


Fig. 7.—Typical stress-strain diagram in compression for sand-cast phosphor bronze.

Hardness.—The hardness of a bronze, *per se*, is no reliable criterion as to its suitability for gear work, although, given knowledge of the analysis and other physical attributes, it forms a useful guide, as it is a good indication of the density of a bronze, which property has a decided influence on its value. Brinell tests on bronze should be normally conducted with a 1,000 kilog. load, and a 10 mm. ball, but much useful information can be obtained for

research purposes by using loads down to one-quarter of this, and thus using the test as a compression test where circumstances do not allow of a full compression test being made.

Resistance to Compression.—A full stress-strain diagram, such as that shown in Fig. 7, of a bronze under compression, is, if correctly interpreted and judged in conjunction with other features, a very useful guide to its likely performance in service, as, of course, is quite logical, considering that the actual service conditions embody high compressive stresses.

In considering physical properties and tests on cast bronze, it cannot be too strongly emphasised how extremely important it is to cut test-bars out of the actual castings themselves. Whilst this method is necessarily expensive and impracticable in large castings, the more usual and cheaper method of relying on test-bars cast nearly to size, either integral with or separately from the castings themselves, gives in very many instances wholly misleading results. These are often in no way indicative of the physical properties of the castings owing to the pronounced "mass effect."

To illustrate this point, the author prepared a number of test-pieces a month or so ago for the benefit of the B.E.S.A. Committee drawing up specifications for cast bronze, the results of which are embodied in Table I. Whilst the physical test results on the rims themselves could undoubtedly have been improved, the results indicate how misleading test-bars attached to the castings can be. It is appreciation of these limitations of cast bronze, therefore, which has led to improvements made over the simpler methods of casting—namely, chilling, die-casting, and latterly, centrifugal casting.

TABLE I.

INFLUENCE OF MASS ON THE TENSILE STRENGTH AND ELONGATION OF SAND-CAST BRONZE.

	Max. Stress. Tons/Sq. In.	Elong. %
Cut from rim 14 in. O.D. × 10 in. bore × 1½ in. width	15·5	7·5
Cast attached to rim	17·8	15
Cut from rim 14 in. O.D. × 10 in. bore × 2½ in. width	14·25	7
Cast attached to rim	18·25	17·5
Cut from rim 14 in. O.D. × 10 in. bore × 3½ in. width	13·6	6
Cast attached to rim	18·3	19

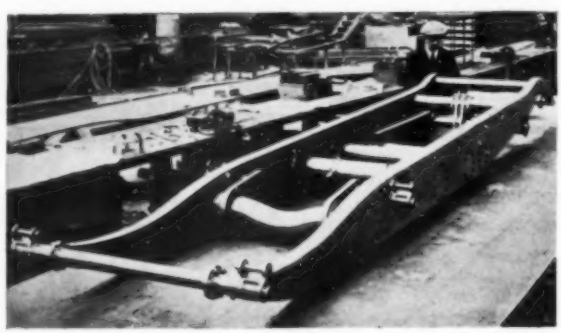
ANALYSIS.	%
Copper	88·04
Tin	11·51
Lead	0·02
Zinc	0·01
Iron	0·02
Phosphorus	0·35

Whilst the ordinary methods of casting in sand have perforce still to be used where limitations of size or features of design preclude casting in chills or centrifugally casting, the stresses permissible on castings made in this manner are by no means so high as those made by more modern methods. Nevertheless, the experience gained in these later methods of casting gear blanks can be of immense service in making sand-cast blanks. They illustrate the type of structure and the best physical properties of which a bronze is capable, and provide the *desiderata*, previously unknown, to aim for in even sand casting. By appreciating cause and effect and realising the various diverse factors both in composition and method of casting, which produce the most desirable attributes, we can go an appreciable way towards obtaining these in the limited scope afforded by sand casting.

Following the recent amalgamation of Allen-Liversidge, Ltd. with the British-Oxygen Company, Ltd., Mr. A. Bede Harrower has been appointed Publicity Manager to the British-Oxygen Company. In addition to his work for the British-Oxygen Company, he will continue to act as joint editor of "Industrial Gases."

Record-breaking Qualities of British Steel.

THE double success achieved by Capt. Malcolm Campbell at Daytona Beach will prove a valuable asset not only to British motor-car manufacturers, but to the whole field of British trade abroad. It will show to the world that in quality of materials, skillful design and constructive genius this country continues to give a lead to progress. Captain Campbell is to be congratulated on the achievement of his main purpose in establishing such a remarkable record with the "Blue Bird," an achievement which demanded fearlessness and determination together with confidence, not only in himself, but in the ability of the car to withstand the heavy stresses to which every part is subjected when travelling at such a phenomenal speed. The spirit shown by this indefatigable motorist in establishing a new world's land speed record will earn for him a great reception when he returns home, and the fact that he has also set up a record for a British "Baby" car will make public appreciation more widespread. It is a magnificent performance, and he has done a very real service to British industry. He relied implicitly on the quality of materials employed and the skill by which the various parts were made and assembled. That he experienced no trouble with any of the parts is not really surprising, as we understand that one steel in particular was tested at stresses many times greater than the normal stresses for an ordinary racing car.



Nickel Steel Chassis for the "Blue Bird."

Practically all the steel work for this car was made at Sheffield, and many notable firms participated in the construction of this record breaker. The English Steel Corporation, for instance, made the massive chassis assembly, the crankshaft of the Napier engine, the front and rear axles, and the gears, as well as many small parts, at their Vickers' Works. All these parts were made of high-tensile alloy steels. The chassis assembly, which is shown in the accompanying illustration, is an interesting piece of engineering work. The construction is unusual, and consists of two side members similar to the pressed steel members used in ordinary automobile practice, but heavier, joined by tubular cross members. The side members are of sheet steel, ¼ in. in thickness, the overall length being 16 ft., with a depth of 11 in., while the tubular cross members are made as forgings. The whole assembly, including the sub-frame members, brackets, spring shackles, and all bolts and nuts used, is made of 3% nickel steel.

Many important parts were made by Messrs. Thos. Firth and Sons, Ltd., including the twelve-cylinder forgings, camshaft forgings, inlet valves, master connecting rods, propeller shaft, extension forgings, the timing gears and parts made from bar steel. Messrs. Hadfields, Ltd., and W. A. Tyzack and Co. also participated in the work, the former being responsible for the exhaust valves, while the latter made the clutch plates.

The work in the production of this car was involved, and it was considered desirable to have it distributed for various reasons, but a brief review of some of the alloy steel parts gives an indication of the reliability of British manufacture which is characteristic of the highest quality.

Aspects of Carbon Control in the Cupola

By H. W. Keeble.

Various factors are discussed in connection with carbon control of cupola-melted cast iron.

RECENT years have witnessed a great forward push in the application of scientific control in the realm of industry. The foundry to a great extent has participated in this move. The cupola is regarded now, not simply as a "furnace," but as a melting-unit which is operated under definite technical principles, coupled with practical observations. Despite these encouraging conditions, there are still difficulties. The mechanical strength of the product of the cupola is dependent to a great extent upon the type of structure developed; this, in turn, is decided by the amount, size, and distribution of the graphitic carbon and the amount in solution as iron carbide, or, in other words, the total carbon content. Yet the absolute control of the carbon content of cast iron melted in the cupola seems difficult, according to general practice, to attain. The following notes will discuss various aspects of controlling the total carbon of grey iron melted in a cupola.

The Importance of the Carbon Content.

The T. carbon percentage of grey cast iron varies in everyday practice from 2·7% to 3·7%. The amount of carbon in solution as iron carbide directly controls the type of matrix formed. The amount of free carbon—*i.e.*, graphite—determines to a very large extent the mechanical strength values and physical characteristics of the matrix. The form and distribution of the graphite constituent makes or mars the best type of matrix one could produce. High graphitic metal has an open grain, facilitating sponginess and porosity and revealing itself under the pressure test. The higher the T. carbon the greater the difficulty in controlling the graphite structure. On the other hand, low graphitic iron frequently has an uneven hardness, hard spots being present. This variation in hardness is caused by the graphite segregation. It also has a greater shrinkage. Late years have shown the necessity of a comparative low carbon content for high-duty iron. It is an established fact that metal of 3·0% T. carbon is superior, other things being equal, to irons with 3·5% T. carbon. At the same time, it will be readily acknowledged that it is far easier to produce metal from the cupola with the latter T. carbon content than with the former. This statement is endorsed by the fact that most cupolas produce iron with a T. carbon content of 3·1 to 3·6%. Mitinski[1] and Osann[2] have advocated the use of eutectic metal for high-duty irons. It is well known that the eutectic point of the iron-carbon binary system is 4·3%, but silicon and other elements reduce this value. For example, 1% silicon lowers it to 3·63%, whilst with 2·0% silicon and 1·0% phosphorus the eutectic condition is at 3·33% carbon. Thus, for every composition there is a eutectic value of carbon which, if obtained, will eliminate the presence of "kish" graphite. These irons of eutectic constitution are immune from growth on repeated heating and cooling, free from segregation, and owing to eutectic composition there is minimum shrinkage. This striving after eutectic metal may be the real theory underlying the varied processes for the manufacture of high-duty iron. All these facts emphasise the importance of the carbon content, and the need for strict control.

1 "Eutectic Cast Iron," by Mitinski. *Foundry Trade Journal*, vol. 39, page 413.

2 "The Manufacture of High Quality Cast Iron," by Prof. B. Osann. *Foundry Trade Journal*, vol. 39, page 448.

General Facts Concerning Carbon Content.

General experience proves that metal melted in a cupola "picks up" or absorbs carbon, resulting in an increased carbon content. The amount of silicon, phosphorus, and manganese present materially affects the total carbon content and influences the amount of "pick up." Reviewing chemical analysis, variations in the silicon content do not appreciably effect the T. carbon content, but the tendency is for the carbon to decrease whilst the silicon increases. Low-phosphorus irons seem to be associated with high T. carbon percentages. Manganese, according to Turner, leads to an increased solubility of carbon in iron at high temperatures, and Pinsl[3] considers that with a high percentage of manganese it may help to retain the "kish" or hypereutectic graphite of pig iron in the remelted metal. It has also been found that some types of cokes give higher T. carbon contents than others. Variations in the blast conditions usually produce changes in the T. carbon content of the metal. Undoubtedly cupola control is the solution to the question of carbon regulation.

Aspects of Total Carbon Control.

Let us consider what happens to the metal charge as it sinks down the cupola shaft and the molten iron is tapped out at the metal hole. The descending charge meets hot gases, becomes heated, and carbon is deposited according to the gas composition, temperature, and its velocity up the shaft. As the melting zone is reached the metal fuses. If steel scrap is included in the charge it takes up some of the deposited carbon until it is in equilibrium for the particular temperature developed in the melting zone, and then melts. The fluid iron drops in small globules through the interstices of the bed coke. Here it is played upon by the blast, which is either reducing, neutral, or oxidising, dependent upon the volume and pressure of the air supply and the amount of coke available. The iron now settles in the hearth or well in direct contact with incandescent coke. When sufficient has accumulated, it is tapped out for casting. The factors which affect the T. carbon content after passing through the above operation are enumerated below, and will be considered in turn:—

(*a*) Initial total carbon content of materials charged.
(*b*) General cupola operation.
(*c*) Atmosphere at the melting zone.
(*d*) Time of contact with the fuel.

Factor (*a*).—In the course of normal working conditions over a period with the cupola, the charge pig iron used varied from a hæmatite iron through the ordinary scale of No. 3 irons down to a cold blast refined iron. Nothing else in the charge or melting practice was altered. The scrap was off the same heap, the coke used for the bed and charge splits was the same in quality, size, and quantity. The blast conditions were as usual, the only variable being the particular pig iron used, its amount being 50%. 10% steel scrap was incorporated in the charge. Examining the analysis figures for the resultant metal, embodying the above-mentioned classes of iron, no variation in the T. carbon content was revealed. This was rather surprising in view of the fact that the pig-iron T. carbon contents ranged from 3·00 to 4·09%. The average T. carbon content of the cast iron was 3·2%, the extremes being

3 "Die Giesserei," 1928, No. 52, pp. 1292–1301.

3·1 and 3·33%. With these conditions the initial T. carbon content seemed in no way to influence the T. carbon content of the final metal, as the extremes noted above were not obtained when expected, by reason of the pig iron employed in the charge. Using up to 15% steel scrap did not have any important effect on the T. carbon content, although its presence was seen in closing the structure and in the higher shrinkage. Users of high steel scrap percentages find it lowers the T. carbon content of the iron. Thus, one is forced to the conclusion that the T. carbon content of the metal charge has little influence on the final T. carbon content after passing through a cupola operating under standard conditions.

Factor (*b*).—The general method of working a cupola has an important bearing on the final carbon result. A deep well or hearth will produce iron with a higher T. carbon content than with a shallow hearth. The use of a receiver or forehearth with a cupola, helps to produce low T. carbon iron. Tuyère area and blast conditions will be considered under (*c*). The size of the coke has its influence, for Mackenzie[4] has found that large cokes (unable to pass through a 2 in. sieve) will lower the T. carbon percentage as obtained after using smaller-sized coke. The size of the steel scrap, according to Hudson[5] and Mackenzie,[6] bears no relation to the T. carbon content of the metal. It affects the speed of melting, and, indirectly, the carbon content, although Pinsl, in the course of his investigations, obtained the lowest T. carbon result with small-sized scrap, probably due to the last consideration. Fast-melting units give lower T. carbon iron than slow-running cupolas.

Factor (*c*).—Probably this point and (*d*) constitute the most important factors with regard to cupola carbon control. The atmosphere of the melting zone is dependent on a combination of several influences. They are blast volume and pressure, tuyère area, physical characteristics of the coke, including reactivity and size, and ratio of ash to fixed carbon in the fuel. Usually the melting zone atmosphere is either neutral or oxidising. With oxidising conditions the T. carbon content is lowered and greater losses of silicon and manganese are experienced. After careful study, the writer is of the opinion that if carbon is eliminated it is by oxidisation. Oxidising conditions are supplied by the use of excess blast volume and high pressures. Ample tuyère area is always advisable for most efficient cupola operation. The coke also plays a part in this, for some cokes are far more active in combustion than others. The coke size also has an effect. Soft cokes, provided the temperature is developed, appear to give irons rich in carbon, whilst hard cokes produce the reverse conditions. The idea is put forward by Mackenzie that each type of coke used, dependent on its physical structure and analysis, produces a definite T. carbon content in the metal.

Factor (*d*).—Most observers agree that the temperature generated and the time of contact of the fluid metal around the coke exert the greatest effect on the T. carbon content. Lemoine[6] states that by adjusting the weight of charges, and pressure and volume of air supply, it is possible to obtain iron with 2·00% T. carbon when it drops down in front of the tuyères. The difficulty is to prevent carburisation as the fluid metal falls from one piece of coke to another in the hearth. He also says that experience proves that the iron globules can pick up as much as 0·5 to 0·8% carbon in rapid contact with lumps of the incandescent coke of the bed when free from slag. This brings in the question of the ash quantity of the fuel used. High ash cokes produce more slag, thereby covering up the coke surface, preventing intimate contact of the metal necessary for carburisation. Also, it is obvious that the amount of coke present, dependent on the depth of the cupola hearth, is an important aspect. The smaller the coke the greater the surface area exposed to the passing of the metal drops. This evidently is the explanation of Mackenzie's finding, mentioned in (*b*). As the temperature of the well is lower than that of the melting zone, the temperature of the metal may be assumed to be gradually falling to that of the hearth. If, by slow melting, saturation has been established, "kish," or hypereutectic graphite, will be ejected out of solution as the temperature drops, appearing in the ladle as a scum. This is fairly common in blast-furnace practice, where great differences exist between the temperatures of reduction zone and the hearth. Rapid passage through the cupola partly promotes the conditions necessary for a low T. carbon in the final iron.

4 "Cupola Melting of Steel Affected by Coke Properties," by J. Mackenzie. Presented to Sheffield Conference of the I.B.F., 1928.

5 "The Melting and Casting of High Duty Irons," by F. Hudson. *Foundry Trade Journal*, vol. 31.

6 "High Test Cast Iron," by R. Lemoine. French Exchange Paper to American Foundrymen's Association, 1929.

Conclusions.

The summary of the foregoing remarks is interpreted into practical conclusions below. These conclusions, in order to meet the needs of practice, may be classed under two headings—

(1) Producing Iron with Constant T. Carbon Content.

(2) Producing Iron of Low T. Carbon Content.

Considering (1) (Producing Iron with Constant T. Carbon Content): Everything must be kept constant. Use a definite amount of bed coke and employ a definite weight of fuel throughout between the charges. The coke must be regular in quality and size, not a mixture of "large" and "fines." Constant amount of flux must be used. The scrap component of the charges must be uniform in section, to ensure regular melting, as also the weight of the metal charges. Variation in the blast volume supplied is to be avoided, until at end of blow, when it may be reduced to avoid scouring of the lining. The metal should be tapped out at definite intervals of time. A combination of these precautions will give a reasonably constant T. carbon content in the metal.

Considering (2) (Producing Iron of Low T. Carbon Content): When endeavouring to produce low T. carbon iron the following points should be watched. Cut the amount of bed and charge coke, as consistent with hot melting, to a minimum. The coke to be preferably in large-sized pieces and hard. Use a cupola with a shallow hearth and a receiver. Employ excessive blast volume at higher pressure. This must be carefully studied in order that proper allowance may be made for the higher silicon and manganese losses which occur under these conditions. Practice a constant metal tap; this automatically takes place when a forehearth is used. Use high percentages of steel scrap. Operate the cupola at maximum melting rate. It is worthy of note that Piwowarsky found that the maximum melting rate was coincident with the highest thermal efficiency.

The British Trade Exhibition at Buenos Aires.

Organised by the Federation of British Industries, a delegation of leading industrialists has left for South America to attend the British Trade Exhibition, which is to be opened in Buenos Aires in March. Arrangements have been made for members of the delegation to meet leading business men of the Republic and to study industrial conditions in that country, while it is expected that they will be invited to visit and inspect typical industrial establishments. The delegation consists of the following gentlemen:—Mr. V. Watlington, chairman of the B.E.A.M.A.; Mr. Alexander Spencer, chairman of George Spencer, Moulton and Co.; Mr. L. E. Mather, Messrs. Mather and Platt; Mr. Robert Goudie, British Machine Tool Makers; Mr. R. C. Rootes, Messrs. Rootes, Ltd.; Mr. J. L. Battersby, Messrs. Battersby and Co., Ltd.; Major F. P. Scott, Messrs. A. V. Roe and Co., Ltd.; Mr. S. C. Goering, Messrs. Babcock and Wilcox, Ltd.; Mr. J. G. Anderson, Whitehorse Distillers, Ltd.; Major Charles Prett, Messrs. R. A. Lister and Co.; Mr. W. A. C. Nation, Messrs. Richard Harwood and Son, Ltd.; and Mr. Mark Firth of Messrs. Thos. Firth & Sons, Ltd.

Modern Steelworks Cranes

Steelworks Cranes must be carefully and scientifically designed to give maximum efficiency.

The materials and workmanship involved in their construction must be of outstanding quality.

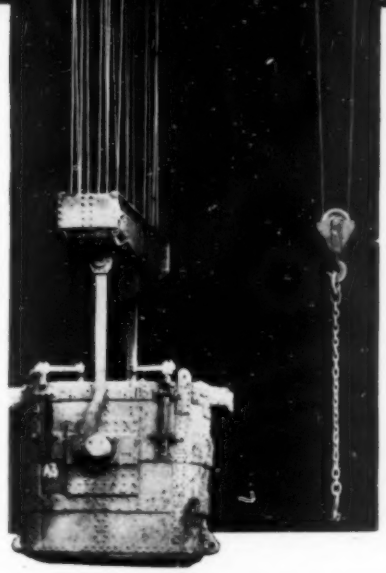


Fig. 3.—100-Ton Double Trolley Ladle Crane.

UNDER modern industrial conditions, the necessity for utilising the best available machinery for lifting, conveying, and lowering heavy loads is becoming more and more apparent. Especially is this true of steelworks in which the plant is usually in continuous operation, and during which time the mechanical appliances are subjected to fumes, dust, and heat inseparable from the manufacture of steel. These conditions necessitate that all machinery in steelworks must be designed and constructed so that it will operate efficiently and be practically immune from possible breakdown. Probably no type of mechanical appliance installed in steelworks is subjected to more severe and abnormal service than overhead cranes, and as they are in constant operation, both day and night, doubtful design and materials in their construction not only cause frequent stoppages with their resultant loss, but may be disastrous.

The electric overhead travelling crane is undoubtedly the most easily adaptable and the most widely used type of power-driven crane for indoor service in a steel plant. It will serve a larger area of floor space within its own travelling restrictions than any other type of permanent lifting gear. These cranes are designed for three motions, which include hoisting, cross traverse of the crab, and longitudinal travel of the whole crane. Each motion is arranged so that it is independent of the other motions by separate controllers situate in a control cage. The so-called multiple motor arrangement results in a single mechanism, and ensures greater reliability and higher speeds in working than is possible with a single motor driving through the medium of friction clutches. For transmitting power from a central point to a number of independent cranes, electricity is unrivalled; its efficiency and flexibility is exceptional for this purpose, and there is no limit to the amount of power that may be transmitted by a single line.

The overhead travellers in steelworks are of a special character, and are divided into two classes: for hot and for cold metal; each class is divided into groups. Thus, for coping with hot metal, modern installations include forge, dipping, and ladle cranes—soaking pit and stripper cranes,—and charging machines; while for handling cold metal, including pig iron and many forms of finished material, such as plates and sections, the magnet crane has much to recommend it.

This type of crane consists of two main parts, the bridge and the crab. The bridge comprises two main girders, which are fixed to end carriages mounted on runners or tram wheels. The girders forming the bridge may be of compound section, plate-box section, lattice-box section, which usually involves Warren bracing, and the single web-lattice section with outrigger, the particular design depending largely on the capacity of the crane and the span between the runners. In designing the lattice girders, which are used for heavier lifts and wide spans, the top boom must be sufficiently strong to carry the wheel load of the crab over unsupported distances, which occur between the connections of adjacent bearing members of the girder, as the local bending stresses thus set up are in addition to the normal compression stress in this boom. Cross-whipping must be avoided when the crane is travelling, and, to give rigidity to the whole bridge structure, large gusset plate connections are a necessity on the end carriages. Built girders are usually built with an initial camber of 1 in. per 100 ft. span. The bridge is traversed by an electric motor which is geared to a shaft running the full length of the bridge and further geared to a tram-wheel at each end.

The crab consists of the lifting machinery mounted on a frame, which in turn is mounted on runners and fitted with suitable machinery for traversing the crab to and fro across the main girders of the bridge. Wire rope has now superseded the use of chains. Its use possesses many advantages, among which may be mentioned steadier and more silent running obtainable. The actual distribution of the load on the crab will depend to a considerable extent on the number of parts of rope involved in lifting the load and the position of the load rope return pulleys on the crab frame, but the design and material should be such that the deflection of frame members must be reduced to a minimum.

For handling molten metal, special ladle cranes are designed, which are usually fitted with two crabs—the main crab running on the top booms, while the auxiliary crab is

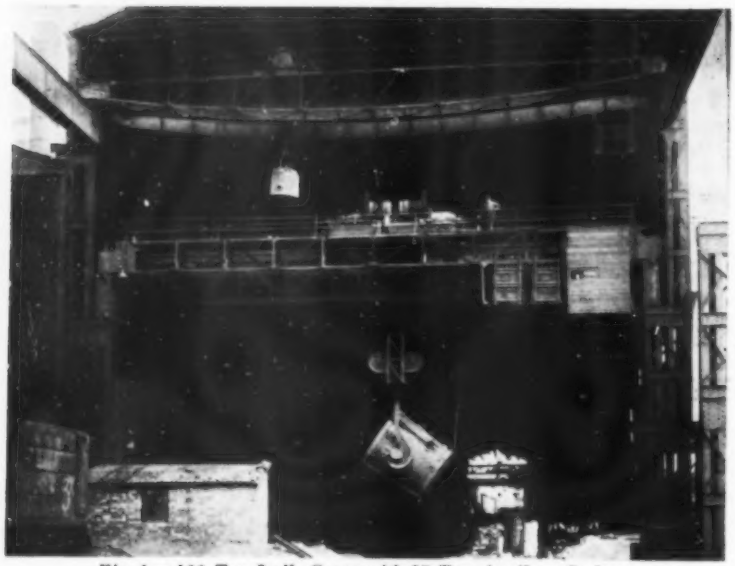


Fig. 1.—100-Ton Ladle Crane with 25-Ton Auxilary Crab.

arranged between the girders and runs on the lower flanges. The main crab has two barrels arranged so that the hoisting ropes pass outside the girders to sheaves attached to a lifting beam, from which the ladle is suspended. Some excellent examples of these large ladle cranes are shown in the illustrations. The crane shown in Fig. 1 is designed by Messrs. T. Broadbent and Sons, Ltd., and represents a 100-ton, 5-motor crane having 65 ft. span, with a 25-ton auxiliary crab. Brief particulars of the speed of operation and the capacity of this crane are as follows :—

Height of lift, 45 ft.

	Ft. per Min.	H.P. Motor.
100 tons—Main hoist	8 ..	100
Main cross traverse	80 ..	25
25 tons—Auxiliary hoist	20 ..	60
Auxiliary cross traverse ...	100 ..	11½
Longitudinal travel	120 ..	60

It will be noted that the auxiliary crane is being used for tilting the ladle. There are four of these cranes installed at the works of Messrs. Steel, Peech and Tozer, Ltd., Sheffield, and all four are running on one track, which is nearly half a mile in length. The small crane shown above the ladle crane in this illustration is a 15-ton, 3-motor crane, used for general purposes, and shown carrying a scrap bucket.

Another crane of this class designed and constructed by the same firm is shown in Fig. 2. This has a similar lifting capacity, is equipped with 5 motors, and has a span of 60 ft. The motors, which are totally enclosed, are continuous rated for a period of 60 mins. with a temperature rise not exceeding 90° F. It is designed to withstand a 100% momentary overload and 50% overload for periods of 5 mins., without injury to any mechanical or electrical equipment. The following particulars in connection with this crane are of interest :—

Height of lift, 31 ft.

	Ft. per Min.	H.P. Motor.
100 tons—		
Main hoist.....	5 ..	50
Main cross traverse	75 ..	25
25 tons—		
Auxiliary hoist	20 ..	50
Auxiliary cross traverse .	100 ..	10
Longitudinal travel	100 ..	50

Voltage — 220 D.C.

Two of these ladle cranes have been installed at the works of Messrs. Lanarkshire Steel Co., Ltd., together with two 6-ton overhead box-charging machines, and a 7-ton ground type bloom charging machine.

Some typical installations of heavy overhead travelling cranes recently constructed by Messrs. Craven Bros. (Manchester), Ltd., include a 120-ton 5-motor double trolley steel foundry ladle crane, 55 ft. 3 in. span, at the works of Messrs. Thos. Firth and Sons, Ltd., Sheffield, and an ingot stripping crane, 65 ft. span, for stripping 5-ton steel ingots, giving a maximum force of 100 tons at Messrs. Steel, Peech, and Tozer, Ltd., also of Sheffield. For handling hot ingots, the modern cranes are provided with semi-automatic tongs, which are frequently used to fulfil a variety of functions, such as stripping ingots from their moulds, charging and withdrawing ingots from the soaking pit, and lifting and subsequently replacing the soaking-pit cover.

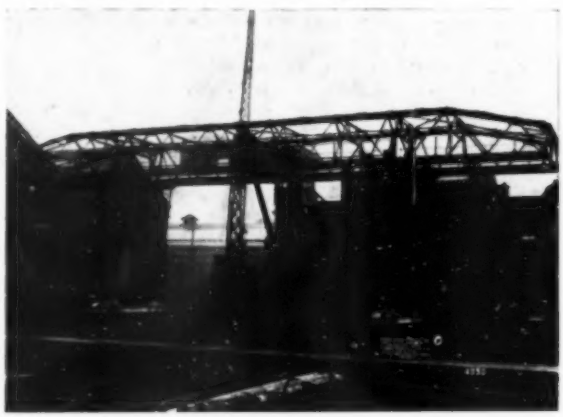


Fig. 4.—15-Ton "Goliath" Crane.

Fig. 2.—100-Ton Ladle Crane on a 60 feet span.

A recent design of a 100-ton ladle crane is that installed at the works of the Partington Steel and Iron Co., shown in Fig. 3. This crane, which was designed by Messrs. Craven Bros., is a 5-motor double-trolley crane.

(*Continued on page* 156)

Welded Steel Structures

Part II.

By Edward Dacre Lacy.

In spite of many handicaps, welded construction is increasing in importance and in the variety of its applications.

AT the present time, when the primary industries of the country are so depressed, all manufacturers and engineering concerns must cut down as far as possible their production costs. It is, therefore, the duty of all consulting engineers, designers, and purchasers of raw material to study every available process reducing works costs.

Already, in many fields, welding has proved over and over again that by utilising this process in new construction and repair work a great deal of expenditure can be saved. Many cases have recently come to light of the cheapness of

The Godavari Bridge, India, which has recently been enlarged by welding.

welding as against casting, and it is claimed by the advocates of welding that the process is more economical than that of riveting.

In connection with the erecting of steel structures by this process, welding means the elimination of all marking-off and drilling of joists and angles, the members being cut to length and welded-up either in the shop or *in situ*. Also accuracy in fitting is not essential, as all small spaces can be quickly filled up with deposited metal, which is equal in strength and solidity to the original member. Again, welding entails the minimum number of loose tools and component materials, and therefore offers considerable advantage over other methods of construction, as it reduces the weight and cost of the structure. In addition, roof trusses can often be welded in the workshop, reducing the work to be carried out on the site to a minimum. Conversely, it is at times more economical to undertake the welding work on the building site and not in the workshops.

A rapid development and extension in the use of reinforced concrete for constructional work has brought to the front a number of problems connected with its practical application. In the past methods employed to join reinforcing bars to girders and meshes left considerable room for improvement. The present system of "tying" members together with iron wire has many disadvantages, as the method is mechanically unsound, and has practically no strength. Also, a beam or girder structure assembled in this manner becomes distorted, whilst the tied pieces are liable to shift when the concrete is poured into the moulds.

Various recognised authorities have expressed an opinion that the adoption of electric welding entirely prevents the occurrence of these defects and at the same time shows considerable economy in time and labour. The application of the process is simple, and requires no special skill on the part of the operator. In the construction of beams and frames consisting of two or more main bars, and a number of minor rods or wires placed across them, the joints are made by a single "tack" weld. Where rods join or cross one another they are arranged to lap or lie adjacent to one another for a length of 2 in. or 3 in., and a run of welding is made along the V so formed between the rods. A girder or beam with electrically welded reinforcements is rigid at all its joints, and can, therefore, be handled and placed in position without liability to displacement of the main or subsidiary members.

Some years ago several timed tests were carried out at a shipyard where concrete barges were built, in order to ascertain particulars relative to the speed and economy secured with electric-welded connections. It was then clearly shown that a labour economy of 33⅓% was effected by substituting arc welding for the method of tying by wire.

As regards cost, it has been found that with a Number 10 electrode, at a price of 2d., it is possible to make 20 joints, equivalent to 10d. per 100 joints.

In regard to the use of welding in buildings, amongst the first to be erected in England were the stables in the old Olympia building, which were built in 1920. The building covered an area of 9,000 sq. ft., the span of the roof trusses being 14 ft. All the steel parts were cut to length and delivered to the site ready for erection, where two welders and four labourers obtained an output of ten complete trusses per day.

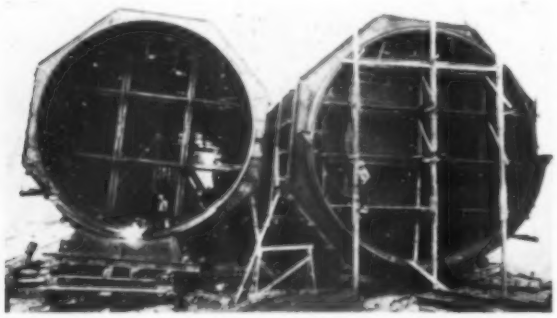
Another building in which electrically welded steel-work was involved was the factory constructed for the Galvanising Equipment Co., Ltd., a description of which will be of interest. It was a skeleton steel building, the walls and partitions being constructed of hollow blocks which take no weight, the whole weight being carried by the steel stanchions. The factory was of one storey, and occupied a total area of 14,000 sq. ft., having a length of 200 ft. and a width of 70 ft. The main truss had a span of 40 ft., and the wing truss a span of 15 ft. The height from floor level to the apex of the roof was 27 ft. The gables were constructed of H-section uprights, whilst the principals for the gables were of channel section resting on the H-section uprights. There was a total of sixteen main trusses and thirty-two wing trusses, excluding the gables.

Factory for the Galvanising Equipment Co., Ltd.

The whole of the steel-work was constructed by electric arc welding, and no bolts or rivets were at any time used in the construction of the building. The delivery of stanchions and roof trusses was commenced in August, and the whole of the steel-work was finished and completely

erected early in October. Therefore the total time taken to erect the whole structure was nine weeks, in spite of delays in delivery of materials. It is satisfactory to note that the roof of the building was strong enough to carry an overhead runway. The electric power used on the job was obtained from the local supply company, so that the electrical plant used consisted only of transformer, choking coils, electrode holders and cables, and shields for operators' use.

Major James Caldwell, J.P., M.Inst.C.E., M.I.E.E., who was partly responsible for the erection of an extension to a foundry belonging to Messrs. Cowlishaw, Walker and Co. (1920), Ltd., and which included the supply and erection of a runway for a 20-ton electric overhead crane, was particularly impressed by his experience in the use of electric welding for the erection of factories. He stated that the experience gained when executing these works proves that the adoption of electric welding saves time, labour, and material, as compared with riveted jointures. The design of members is simplified. Lighter sections can be used. The design of parts is simplified. Stock sections can be utilised to build into stanchions, gantries, roof trusses, inways, etc., which would be impracticable for riveting. No gussets, palms, or cover straps, essential for riveting, are required for welded joints. The members for a roof truss, or a stanchion, may be ordered cut to length from the steel-works, bundled for transport, and assembled on the site. No drilling, punching, or reaming is needed, and, therefore, there is no delay in erection because holes do not come fair.



Arc-welded Detroit Vehicular Tunnel Sections on Assembly and Launching Ways.

A roof truss, for instance, is assembled on the site from cut-to-length members to a template or chalk line on the floor, welded up in that position, and is then ready for lifting to its place.

In Belgium and France lattice-steel masts and towers for transmitting electricity have been manufactured by arc welding, which shows an appreciable saving in weight over riveted construction, because there is no weakening of the members by riveted holes, and no reinforcements at the joints either by gussets or straps. The reduction of weight due to the absence of rivets is from 3% to 5%.

Light masts for telegraphy which have to support the tensions of the conductor and the wind force on the structure, are more rigid when built up by welding than when riveted. Exhaustive tests of welded masts confirm that these structures are much stronger than those erected by means of riveting, and the average cost of construction shows a 40% reduction in favour of the welded mast.

Gas-holders have been erected in U.S.A., South Africa, and Australia by means of all-welded construction. Perhaps the welded gas-holder at South Melbourne, Australia, which measures three million cubic feet, with 200 ft. diameter, and maximum height 105 ft., is the largest gas-holder to be welded up to the present.

The welding of pipe-lines has, perhaps, made far greater strides in U.S.A. than in any other country, owing to the large demand for large pipe-lines for the transmission of crude oil, natural gases, and coal gas under high pressure in the field. In spite of the progress made in America in 1927, a welded hydraulic pipe-line was laid in South Africa under the supervision of the Electricity Supply Commission of that country. This pipe, which was included in the erection of the Sabie River Hydro-electric Power Station scheme, was stated by the President of the South African Institution of Electrical Engineers to be larger than any pipe-line constructed by electric arc welding at that time, although the year before a pipe-line approximately 22 miles long and 22 in. and 24 in. in diameter, was erected in America.

It is a common mistake, for those who are considering the erection of a building by means of welding, when estimating the cost, to apply the usual overhead charges appertaining to a riveted design, after having accounted for the cost of material, electrodes, construction and labour. This is absolutely wrong, owing to the following facts: In a riveted construction neither the cost for current necessary for punching, drilling, or boring machines, air-compressors, water-pumps, etc., nor the fuel necessary for heating the rivets, are calculated separately, but they are usually included under the heading, "General Expenses"—an item which allows also for a certain amount of expenditure in connection with depreciation on the machines which are utilised for the work, and also for interest on the capital allowed for the contract.

In a welded construction, a number of machines may be dispensed with altogether. There are, for instance, no rivets to be heated, no maintenance costs, and no supervision of fires, etc. Further, the costs for designing a welded construction are less than those necessary for a riveted erection, the same applying also to tracing and forging, and the work is done more speedily with the same labour, reducing the cost for building, lighting, and heating. It is, therefore, absolutely necessary to estimate separately for welded structures, and if it is necessary to allow for an item of general cost, the electric current necessary for welding should be included. As a matter of fact, the current of electricity is less than the whole of the cost for the current, depreciation, maintenance of machinery, carbon, etc., which is necessary for erecting a riveted design.

In view of the fact that welding is still in its comparative infancy, it is necessary to govern the design of steel structures erected by this means by past practices and established rules, which explains the fact that welding is progressing slowly but surely, and yet not so fast as some of the advocates of the process would like. It is common sense that those engaged in pioneer work must take certain precautions to safeguard their individual interests, built up from technical knowledge, regarding the value of new methods and materials, and when this is realised, the utilisation of welding for structural purposes will make great strides. A little confidence, however, is necessary to encourage builders and structural engineers to adopt a method of building which is somewhat new to them, but in spite of these handicaps, electric arc welding will undoubtedly play a large part in the erection of steel structures in the near future.

Standardisation in Engineering.

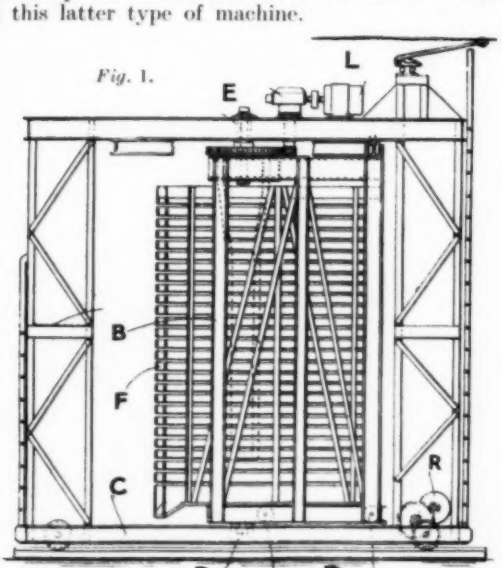
The extension of the work of the British Engineering Standards Association into fields quite outside engineering has made the Council come to the unanimous conclusion that the time is past when the word "Engineering" should appear in either the charter or the title, said Mr. C. le Maistre, Director of the British Engineering Standards Association, in a paper on the "Effect of Standardisation on Engineering Progress," delivered before the Society of Arts recently. The advantages to the country of a single national standard organisation are so immense and so generally recognised that there is every reason to believe that whatever modifications might be necessary could be brought about by common consent. Steps have already been taken in that direction with the great chemical interests, and a new scheme based on equal representation on a Grand Council of the great industries of the country—public works and engineering, chemical, building, and textile—is being evolved.

Some Recent Inventions.

IMPROVEMENTS TO APPARATUS FOR DISCHARGINC COKE OVENS.

THERE are several methods of dealing with coke when discharged from the oven. In plants of moderate capacity, when the coking process is complete and the oven ready for pushing, the doors are lifted and the ram brought into position, and the coke pushed slowly out through a quenching hood, during which time water at a fairly high pressure is used as a quenching medium. With plants of large capacity the method of dealing with the discharged coke is by means of a coke car. Instead of partially quenching the coke as it comes through the hood, it is pushed through a coke guide without the application of water. The machine carrying the coke guide travels along the front of the ovens, and also has a device for lifting the door and swinging it to one side to allow the coke to be dealt with. Recent improvements have been devised in connection with this latter type of machine.

Fig. 1.



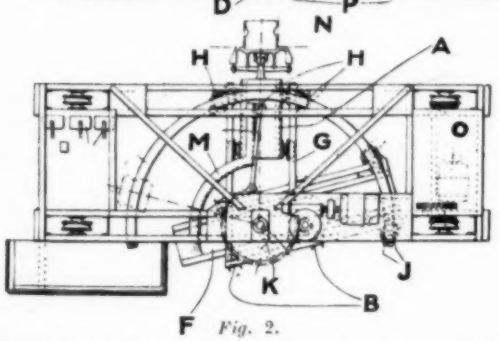


Fig. 2.

The coke guides and door extractors associated with these machines have previously been mounted side by side on a truck and arranged so that, after the removal of a coke-oven door by the extractor, the truck was traversed to bring the coke guide into position, and further traversed after the discharge of the oven to bring the door into position for replacement. In the improved arrangement, the coke guide and door extractor are connected at an angle, and are pivotally mounted on a truck, so that as one is swung out of position the other takes its place.

A front elevation of the apparatus, with the door extractor in position ready to withdraw a door, is shown in Fig. 1, while a plan view showing the gear for racking the door extractor, and for slewing the coke guide and door extractor is shown in Fig. 2. The door-lifting mechanism is carried by a trolley A mounted to run on rails forming part of the structure in which the coke guides are mounted. The coke guides are of ordinary construction, but are movable to and fro within the structure B. This structure comprises two parts, one carrying the rails and the other enclosing the coke guides. These parts are arranged at an angle to one another, and are shown at an angle of 75° in the illustration. The structure is supported on a pivot bearing D mounted on the truck C, while at the upper end a pivot spindle E, carried by a sleeve casting, gives support at the top. The two pivots are arranged one above the other, and at the meeting point of the centre lines of the two parts of the structure. The free ends of the two parts are carried on rollers.

Projecting from the upper end of the structure B, and arranged at an angle to the guide F, are rails G, which support a wheeled trolley carrying the door-operating mechanism, the free ends of the two parts of the structure B being supported by rollers H, J running on a fixed rail. A connecting-rod is attached at one end to the trolley A, and at the other to an arcuate rack K loosely mounted on the pivot E, and adapted to be operated through gearing by an electric motor L. The rod is provided at its point of connection with the trolley A with a roller which engages a fixed guide-rail M, having a straight part and a curved portion, as shown. In operation, with the parts of the position shown in Fig. 2, the motor L is started to move the rack in an anti-clockwise direction, the engagement of the roller with the straight part of the rail M causing the trolley A to travel backward on its rails G away from the oven N, until it contacts with a stop. Further rotation of the rack causes the structure B to rotate as a whole about its pivots to bring the guide F into line with the oven. A second motor is then started to move the guide forwardly on the rollers P into contact with the face of the oven. A motor R, Fig. 1, is mounted on the truck to effect its movement on the rails along the face of the oven battery.

333,294. The Wellman Smith Owen Engineering Corporation, Ltd., and Samuel Stockdale, patentees. (Messrs. J. E. Raworth and Moss, Agents, 75, Victoria Street, London, S.W. 1. Aug. 11, 1930.)

CUTTING MATERIALS FOR TURNING TOOLS.

THE increasing developments in the production of high-duty metals and alloys have necessitated the development of tools to cope effectively with the increased demands made upon them. A recent development of this character refers to tools of great hardness being made by melting a mixture of metals of high melting point, such as chromium, molybdenum, titanium, tungsten, uranium, or vanadium, and metalloids such as carbon, boron, or silicon, with or without other metals, such as iron, cobalt, or nickel, then cooling to produce a finely-grained texture, then finely powdering, then pressing to form the tool, and subsequently or simultaneously sintering by external heat or resistance heating at a temperature which does not destroy the fine texture—*e.g.*, 1,500° to 1,900° C. 400 grms. of powdered tungsten may be mixed with 40 grms. of titanium carbide and melted electrically in a carbon crucible, having carbon terminals in a hydrogen atmosphere. The melt is poured into a copper mould and cooled by water, and is then powdered and shaped in swages under a pressure of 4,000 kilogs. per sq. cm. The shaped bodies are sintered for 12 mins. at a temperature of 1,750° C., in hydrogen below atmospheric pressure, cooled down to 1,500° C. in 40 secs., and then allowed to cool to room temperature in 45 mins. The additional metals or the metalloids may be introduced into the mixture during melting, after pouring from the crucible. The pressing operation may include the formation of holes or recesses in the tool. The bodies may be immediately subjected to a further heat-treatment between 1,000° and 2,000° C. to improve the texture, and may also be subjected to mechanical treatment such as by forging, rolling, pressing, etc., at 2,000° C. The alloy may contain tungsten with less than 3% of carbon.

331,121. G. BREWER, 33, Chancery Lane, London. (Krupp Akt.-Ges., F.; Essen, Germany.)

Business Notes and News

The Use of Steel Furniture Increasing.

Considerable developments have been made during the past few years in the manufacture of steel office furniture and shelving. There has been a great expansion in its use in Great Britain, and although the number of British producers has grown, imports have increased steadily. In 1923 the total value of metallic furniture for hospital and office use, produced in this country, was given as only £54,000. Rapid strides have, however, since been made in domestic production, and it is estimated that the output of steel furniture and shelving is now between £430,000 and £640,000.

During this period of expansion the amount of this kind of furniture imported into Great Britain has shown a steady increase from about £74,000 in 1913 to £156,000 in 1929; and American producers have been successful in maintaining their share of the total import trade. The value of imports of steel furniture from the United States increased from £87,000 in 1925 to £120,000 in 1929. This was approximately 80% of the total imports for these years. Imports from Canada, Germany and France come next in order of importance.

Exports to foreign countries of metal shelving and furniture produced in the United Kingdom were valued at about £60,000 in 1927, £77,000 in 1928 and £107,000 in 1929; to British Possessions, £73,000 in 1927, £85,000 in 1928, and £90,000 in 1929; making total exports worth approximately £130,000 in 1927, £160,000 in 1928, and £200,000 in 1929.

It is apparent that there is a considerable trend towards a more general use of steel furniture, more especially in connection with commercial undertakings, and no doubt as soon as general trade improves further developments will take place on a much larger scale than at present. The possibilities of this class of work offer scope for initiative, particularly in regard to markets abroad, in addition to India and Kenya, which are our most important consumers of metal furniture.

The Lincoln Arc-welding Competition.

Full particulars of the Lincoln Arc-welding Competition, referred to in our November issue, can be obtained from the Lincoln Electric Co., Cleveland, Ohio, who have organised the competition with a view to spreading the knowledge of the uses of arc-welding in industry, and to encouraging manufacturers to make more use of it as a manufacturing tool. The entries will be judged by a Jury of Awards composed of the Electrical Engineering Department of Ohio State University, under the chairmanship of Professor E. E. Dreese, head of the department. Forty-one prizes are offered, the total value of which will be $17,500, and all winners will be notified as soon as the decisions of the Jury are completed. Entries should be addressed to the Lincoln Electric Co., P.O. Box 683, Cleveland, Ohio, and must arrive in Cleveland before October 31; wrappers should bear evidence of having been mailed before October 1, 1931.

The Leipzig Fair.

An event of international significance is the opening of the Great Technical and Building Fair at Leipzig on March 1. This exhibition, which lasts until March 11, is judged by some to be the finest in existence; for it is not like most others, devoted only to individual branches of industry, but it covers the whole field of industrial engineering. An interesting feature of the Fair will be special "live" exhibits and mechanical-motion models for demonstration purposes. Special measures are being taken by the organisers for the convenience and information of visitors, at the Fair itself, while extensive travelling facilities are to be provided for those visiting the Fair from foreign countries.

Closing for Aluminium Development Competition.

Readers are reminded that the closing date of the competition organised by the International Aluminium Bureau for the development of the aluminium industry, is April 1. All entries should be forwarded to the French address of the Bureau, 23-bis Rue de Balzac, Paris, 8.e.

Mr. Walter Lister, author of "Practical Steelmaking," and one of our earliest contributors, having now completed seven years' service at a large modern Steel Plant in Spain, is desirous of an appointment with some home firm. Offers may be sent to "Metallurgia."

D*

Research Work Reports.

The thirty-sixth general meeting of the Deutsche Bunsen Gesellschaft fur angewandte physikalische Chemie will take place from May 25 to 27, 1931, in Vienna. The subject of the symposium will be; *Recent progress in the science of metallurgy with particular reference to light metals.* The arrangements have been undertaken by Geheimrat Prof. Dr. Dr.-Ing. h.c. Specketer, Director of the I. G. Farbenindustrie A.-G., managing-director of the Griesheim Elektron works.

This organisation is one of the leading associations of research workers, scientists, and technologists in the important field of applied chemistry, and we have been informed that a decision has been arrived at whereby interesting and valuable results of its varied activities will be opened to a much wider circle of readers than has been customary in the past. Reports on the results and developments of the work of the association will in future be distributed free of charge, and readers are advised to note the address: Nachrichtendienst der Deutschen Bunsen-Gesellschaft Fur Angewandte Physikalische Chemie, E.V., Geschaftsstelle, Seelze, 197, Bei Hannover.

Steel Firms Amalgamate.

Negotiations regarding a close working arrangement between John Brown and Co., Ltd., and Thos. Firth and Sons, Ltd., have been proceeding for some time. An agreement has now been conditionally arranged for an amalgamation which is expected to produce important economies and to lead to greater efficiency, more particularly in the heavy sections of the steel industry. As soon as it is made effective the way will be clear for consideration of the possibility of widening the basis of rationalisation of the heavy steel industry by bringing other business under one control, thereby augmentinge fficiency and economy in manufacture and marketing of products, and eliminating the cost of maintenance of redundant plants.

John Brown and Co., which already holds an interest in Thomas Firth and Sons, has an authorised share capital of £5,000,000, with considerable interests in the South Yorkshire coalfields, and has steel works in various parts of the country. Thomas Firth and Sons have an authorised capital of £2,000,000 and a complete amalgamation of these two firms would form one of the biggest steel and coal combines in Great Britain.

A Combination to Form New Company.

Messrs. Gibbons Brothers, Ltd., Dibdale Works, Dudley, in conjunction with Messrs. Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, North Road, Holloway, London, N. 7, have acquired from Messrs. Rudge-Whitworth, Ltd., Birmingham, the sole manufacturing and selling rights of the Carburising Compound "Eternite."

In connection with this, and also the acquisition for the manufacture and sale of mechanically-operated furnaces, Hevi Duty Electric type (under agreement with the Hevi Duty Electric Co., Milwaukee, U.S.A.), we understand that Messrs. Gibbons Brothers, Ltd., and Messrs. Wild-Barfield Electric Furnaces, Ltd., are forming a new company under the title of G.W.B. Electric Furnaces, Ltd. The whole of the share capital will be held by the firms named.

Steel for Railways in China.

The railway system in China has been somewhat neglected during recent years, and few orders worth mentioning have been placed in England from that source. During the next two or three years, however, considerable expenditure in this country has been made possible as a result of the decision of the Government in regard to the allocation of the Boxer indemnity. The arrangement, which has been made, allows for an expenditure of three and a half million pounds on equipment for the railways in China. The bulk of the allocation will go on rails, locomotives and rolling stock, while a considerable amount of work will be involved in the supply of axles, tyres, springs, etc., all of which will ensure a succession of very valuable orders for British steelmakers.

Marking Pneumatic Tools Recommended.

The application of the British Compressed Air Society for a marking order on imported pneumatic tools has resulted in a report being issued by the Standing Committee under the Merchandise Marks Act, recommending that imported air and gas compressors and exhausters, and pneumatic tools and appliances, including mining coal-cutters operated by compressed air, whether imported complete or in parts, should be required to bear an indication of origin on sale or exposure for sale in the United Kingdom, the indication being cast, die-stamped, or engraved on the article itself or on a plate securely attached thereto.

Some Contracts.

The Great Western Railway have placed contracts to the value of £27,500. These include the supply and erection of two electric 5-ton goods lifts for the South Lambeth warehouse—to William Wadsworth and Sons, Ltd., Bolton; supply and erection of two transporter cranes and one 6-ton electric overhead travelling crane—to the Wharton Crane and Hoist Co., Ltd., Reddish.

Clarke, Chapman and Co., Gateshead, have received an order for four 5-ton level luffing cranes, complete with transporter bridges, for coal-handling on the Mole at Gibralter. The value of the contract is said to be £30,000.

Commer Cars, Ltd., Luton, Bedfordshire, are to supply the Metropolitan Water Board with two G. 3 type 3-ton lorries, Manchester Corporation with one G. 5 type 5-ton tipping lorry, and Shell-Mex, Ltd., with 12 G. 5 type 5-ton chassis.

The L.N.E.R. announce the placing of the following tracts: four 3-ton crank-operated level-luffing jib portal cranes for Grimsby Royal Dock—The Clyde Crane and Engineering Co., Mossend; one hydraulic coal-hoist for 20-ton wagons for Hull Humber Dock—Fielding and Platt, Ltd., Gloucester; construction of a subway under Redcar East Halt—John Lant, Ltd., Pilgrim Street, Newcastle-on-Tyne; rebuilding of the bridge over the Esk—Furness Shipbuilding Co., Haverton Hill-on-Tees, Durham.

Smiths Dock Co., Ltd., South Bank, are to carry out extensive repairs to the steamer *Blythmore*, which went ashore recently on the Norwegian coast.

John Spencer, Ltd., Globe Tube Works, Wednesbury, has received an order for 15,000 steel poles for Northern Rhodesia. The order, which is one of the largest of its kind hitherto placed, was obtained through the Crown Agents for the Colonies.

The Parsons Oil Engine Co., Ltd., of Southampton, has received the following orders: a 45-h.p. paraffin marine engine for the War Office; a similar set of 35 h.p. for the Egyptian Government; a 30-h.p. set for the Crown Agents for the Colonies, for the river Niger; and five sets of 20 h.p. paraffin engines and other engines, for the Admiralty.

The County of London Electric Supply Company have placed an order with Hick Hargreaves and Co., Ltd., for surface condensing plant with auxiliaries for two 75,000 k.w. turbo-alternators for the new Barking extensions. Messrs. Hick Hargreaves and Co. have also obtained a similar order for two 20,000 k.w. turbo-alternators for the extensions to the Greenwich power station of the London County Council tramways.

Leeds Corporation have accepted the tender of Edward Wood and Co., Ltd., Ocean Ironworks, Trafford Park, Manchester, for the constructional steel framework for the new civic buildings in Leeds. Over 2,000 tons of steelwork will be required, and this will all be manufactured at Trafford Park. The value of the contract is about £30,000.

The contract for the structural steel for the new South Africa Office, Trafalgar Square, London, which is valued at over £13,000, has been awarded to Messrs. Redpath Brown and Co.

The Sentinel Wagon Works, Ltd., Shrewsbury, have recently completed an order for 12 D.G.6 type six-wheeled tipping wagons for the St. Mary's Wharfe Cartage Co., Ltd., Paddington, W. 2. They are to be used for transporting clay excavated during the construction of the new Piccadilly Tube extension.

The Daimler Co., Ltd., Coventry, have received orders for ten C.H. 6 type double-deck 'bus chassis equipped with Daimler fluid flywheel and selective gear-changing system, for the Newcastle-on-Tyne Corporation, and three similar chassis for the York Corporation.

The De Havilland Aircraft Company has received instructions to supply two Puss Moth cabin aeroplanes to the "Asahi," the Japanese newspaper published in Osaka and Tokyo. The machines will be used for the transport of reporters, newspapers and photographs.

The British Thomson-Houston Co., are to supply and install a 10,000 k.v.a. three-phase 33,000 volt. reactor and automatic control switches at the Longford generating station of the Coventry City Council, while the five new double-deck tramcars for the same town are to have B.T.H. power equipment and bodies and trucks supplied by the Brush Electrical Co.

Chesterfield Town Council have placed an order with the Consett Iron Co. for materials for the repair of the beds of 12 gas retorts.

The following tenders have been accepted by the London County Council: Tramways conductor-rails—Frodingham Iron and Steel Co., Ltd.; track rails and fishplates—Dorman, Long and Co., Ltd.; railway bridge at Woolwich—R. Robinson and Co. (Contractors), Ltd.; five electric tramcar traversers—Holt and Willets, Cradley Heath.

The Wellman Smith Owen Engineering Corporation, Ltd., have secured a contract for 1,000 tons of machinery for America. It comprises plant for the production of weldless steel tubing, and will be made at Derlaston, Staffordshire.

The Spanish Andalusian Railways have awarded a contract for 30,000 tons of Welsh steam coal to the British-Italian Coal and Shipping Co., Cardiff.

The Middlesex and Surrey Joint Thames Bridges Committee have awarded a contract to Aubrey Watson, Ltd., Victoria Street, S.W. 1, for a new bridge to carry the Chertsey arterial road over the Thames at Richmond. The value of the contract is stated to be about £191,206, of which the Ministry of Transport will grant 75 % on the cost of bridge and approaches.

A contract for new by-product coke ovens has been placed with Woodall-Duckham Vertical Retort and Oven Construction Company. A battery of fifty-one coke ovens is to be built. These will be capable of producing five thousand tons of coke a week for use in furnaces. The contract also includes the supply of coal-handling, coke-handling plant, by-products recovery plant, and benzol recovery and rectification plant. Under normal conditions, it is estimated that about 750,000 gallons of motor-spirit will be produced a year.

Catalogues and Other Publications.

Several new features and improvements in design are incorporated in two Metropolitan-Vickers Turbo Blower Units recently installed at the Workington Iron and Steel Co.'s works. The blowers are of the four-stage single flow type, and run at 2,900 r.p.m. at normal conditions with a maximum speed of 3,200 r.p.m. Careful attention has been devoted to the design of the inlet and outlet casings, while improvements to the impeller vanes have resulted in the achievement of higher efficiency and strong construction. The turbines are of the Metropolitan-Vickers Impulse Mixed Pressure type, and are supplied with steam at a pressure of 150 lb. per sq. in. superheated 60° F. An illustrated leaflet describing these units may be obtained on application to the Metropolitan-Vickers Electrical Company, Ltd., Manchester.

Industrial accidents, it is said, cost this country £20,000,000 yearly. With a view to starting an accident prevention campaign, Accident Prevention and Welfare Publications, Ltd., have issued an excellent calendar for 1931. It contains a clear exposition of everyday accidents, their causes and prevention, while a number of pages are devoted to first-aid hints. It is recommended for distribution among employees in all spheres of industry, and may be obtained in single copies at 4d. each, or in larger numbers at reduced prices from Accident Prevention and Welfare Publications, Ltd., 321, High Holborn, London, W.C. 1.

The General Electric Company's journal for the period May, 1930 to February, 1931, contains any amount of interesting information, both in the form of technical articles and in general notes on "Progress during 1930," to which a very large part of the journal is devoted. The special articles include those on "Insulation for 132-kilovolt Electrical Apparatus," "The Mass Production of Incandescent Electric Lamps," "The Design of High Power Heavy Oil Engines,' and "Installing Oil-filled Cable." The journal is full of illustrations.

IRON AND STEEL REPORT.

CHIEF interest in the iron and steel markets during the past month has centred on British steel. Users have for long been awaiting lower prices, and it is this factor, in conjunction, of course, with the slackness in the principal consuming industries, that has restricted contract buying, orders as far as possible being confined to parcels for delivery over relatively short periods.

About the middle of last month British steel makers took a decisive step, although it was one which would be welcomed only by those users who complied with the conditions of the rebate scheme, which was introduced in September, 1927. This scheme restricts the benefit of the rebates to consumers of British products exclusively. The amount of the rebate on sections and ship plates has been increased by 5s. per ton, while in the case of joists the rebate allowance has been raised by 10s. per ton, although the price has been increased by 5s., the net result being to cheapen joists to all British users by 5s., and to increase them by 5s. to consumers who do not qualify under the scheme. Although, perhaps, the benefits are not so great as a good many buyers were inclined to anticipate, they will be welcomed by both shipbuilders and constructional engineering firms, who are the heaviest consumers. The rates for delivery to Northern and Midland buyers are now £8 15s. for joists, £8 7s. 6d. for sections, £8 17s. 6d. for ship and tank plates, and £9 2s. 6d. (including surface inspection charges) for frame plates. Boiler plates have weakened somewhat since last report to about £9 5s. per ton for both acid and basic descriptions, with small bars obtainable from re-rollers at round £7 2s. 6d.

With regard to buying conditions in the steel market, these are extremely patchy, and improvement is slow to develop. While some fair-sized export orders have been reported during the past month, there has been no marked expansion in respect of the home market, and in some parts of the country, notably in the Lancashire area, rollers report even quieter conditions at the present time than those which obtained in the closing quarter of last year, due, in a large measure, to inactivity in the constructional engineering branch. A few more orders have come the way of the shipbuilders, but most of the vessels concerned are of relatively small size, and many yards are still idle or underemployed. The consequence is that the call for plates and other steel materials is appreciably below normal, and the same may be said in respect of locomotive engineering. In tool steels no more than a moderate business has lately been done.

Towards the end of last year Continental iron and steel makers tried hard to hold up prices, and for a time some semblance of steadiness pervaded the market. More recently, however, there have been definite signs of reaction, and prices quoted on the British markets for imported materials have shown declines of several shillings a ton, wire rods being about the only section to be maintained.

The recent reduction in Cleveland foundry iron prices is said to have been effective to the extent that Continental competition on the British markets has been appreciably weakened, and some increase in home buying has resulted. Contrary to anticipations, however, there has not so far been any disposition on the part of Midland iron masters to follow the North-east Coast lead, and a determined stand is being made by the former against attempts to depress prices below their present level, which, they say, are already production costs for the majority of pig-iron producers in the Midland counties. While the latter are booking orders which are largely confined to deliveries over a few weeks, consumption in the aggregate seems to be up to what it was in the closing months of last year.

In the finished-iron section a fair demand has been reported for marked bars, though trade in crown quality bars, and the lower grades for the nut and bolt-making industries is poor. In respect of the last named, Continental bars are available at prices which are pounds a ton below the corresponding British rates.

Modern Steelworks Cranes

(*Continued from page* 150.)

Noteworthy also is a recent 15-ton overhead electric travelling crane by this firm, with three motors, arranged if required, also to use a lifting magnet. The motors operate the hoisting-lowering, cross-traversing, and longitudinal travelling motions, giving speeds of 50 ft., 200 ft. and 400 ft. per min. respectively. The rating of the hoisting motor is 75 b.h.p., running at 500 r.p.m., the cross-traversing motor 10 b.h.p. at 750 revs., and the longitudinal travelling motor 30 b.h.p. also at 750 revs.

An important section also of this firm's overhead crane work is mechanical pickling plant, for which is used a modification of their electric driven "Octopus" type having a special automatic drip tray which comes into operation at the necessary period, moving underneath the "baskets" or containers, when these are lifted out of the pickling baths, so as to catch all the drippings. The sheets or other objects are packed in these baskets, and the whole operation of pickling is carried out by means of the overhead crane, carrying and lowering the baskets into the pickling tanks, taking them out again, and conveying to washing tanks, thus effecting a great saving in labour as compared with hand methods.

For outside service the Goliath crane fulfils the same function as an overhead traveller. These are designed and constructed for a lifting capacity up to 200 tons, or more if necessary. A "Craven" crane of this type of 15 tons capacity is illustrated in Fig. 4.

Steelworks cranes in particular must be carefully and scientifically designed to give the maximum efficiency, the materials and workmanship involved in their construction must be of the best, to maintain a good working condition in constant use, and each structure must be absolutely dependable to ensure confidence in its operations with the maximum degree of security.

The Whaling Factory Ship, "Vikingen"

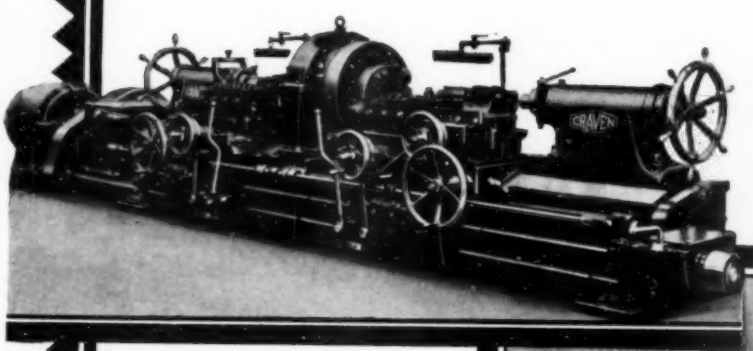
CONSIDERABLE interest was taken in a paper describing the whaling factory ship *Vikingen*, delivered by Commander C. F. Christensen, before the North-East Coast Institution of Engineers and Shipbuilders, on January 30. After reviewing the history of whaling and the types of whales encountered, Commander Christensen gave a detailed description of the vessel itself. The equipment in 1925 of s.s. *Flackwell* as a whaling factory ship, with slipway, proved such a success that it was resolved to build a special vessel for the same purpose. S.s. *Vikingen* was launched in time for the 1929-30 season. Built on the longitudinal system of framing, with tank and working decks and intermediate decks at the ends, this ship was designed for maximum efficiency both as regards carrying capacity and ease of operation. To combat ice pressure, the plating was made extra thick at places where stress was likely to occur, while the stem post was constructed of heavy cast-steel sections, and the rudder strengthened.

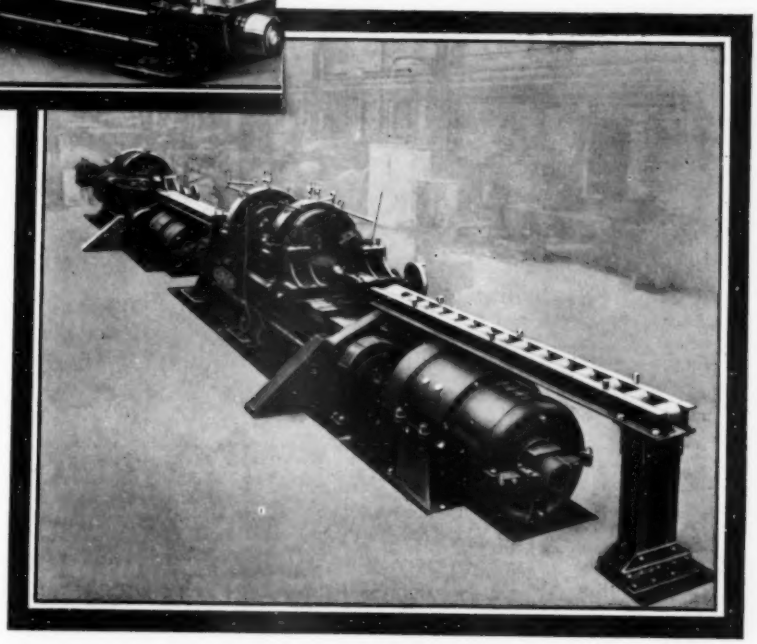
Accommodation arrangements were well considered, the fore-end of the ship being devoted to the crew, galley, messrooms, hospital, and stores, the aft end to the engine crew and "whale-catcher" crews, and the 'midships section to the factory itself. Arranged in much the same way as in all modern twin-screw steamers, the machinery consists of main engines developing 2,000 h.p. at 100 revs. (with shaftings and bearings specially enlarged), and boiler plant in two groups—*i.e.*, four main forced draught oil-fed boilers and two natural draught auxiliary boilers. One of the main features of interest in this vessel is the slipway, up which the whales are hauled by two 40-ton winches. This is constructed of heavy rolled plates, rabbeted into the cast steel corners of the aperture. As it is desirable to have it well down in the water when pulling up whales, water ballast is used to trim the ship. Commander Christensen himself had a very great deal to do with the construction of the *Vikingen*, which was built by Messrs. Swan, Hunter and Wigham Richardson, Ltd., of Wallsend.

COMPLETE INSTALLATIONS FOR THE PRODUCTON OF

RAILWAY CARRIAGE AND WAGON AXLES

MACHINES FOR ENDING AND CENTRING
ROUGHING
FINISHING
BURNISHING
POLISHING





Minimum guaranteed outputs per machine

12 axles ended and centred per hour

6 axles rough turned per hour

4 axles finish turned per hour

6 axles burnished per hour

TO SUIT THE MOST EXACTING RAILWAY REQUIREMENTS

CRAVEN BROTHERS (MANCHESTER) LTD.

Incorporating SIR W. G. ARMSTRONG-WHITWORTH & CO. LTD. (Machine Tool Department) :
Craven Brothers (Manchester) Ltd. : Joshua Buckton & Co. Ltd. : Thomas Shanks & Co. (1928) Ltd.

REDDISH STOCKPORT

MARKET PRICES

ALUMINIUM.

99% Purity	£85	0	0

ANTIMONY.

English	£36	0	0
Chinese	25	0	0
Crude	22	0	0

BRASS.

Solid Drawn Tubes	lb.	10d.	
Brazed Tubes	lb.	12d.	
Rods Drawn	,,	9¾d.	
Wire	,,	8¾d.	
*Extruded Brass Bars	,,	4⅞d.	

COPPER.

Standard Cash	£43	15	0
Electrolytic	46	0	0
Best Selected	44	10	0
Tough	44	0	0
Sheets	75	0	0
Wire Bars	46	8	9
Ingot Bars	46	8	9
Solid Drawn Tubes	lb.	11¼d.	
Brazed Tubes	,,	11¼d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	£0	2	3
‡Ferro Tungsten	,,	0	2	0
§Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
2-4% Carbon, scale 11/- per unit	ton	29	17	6
4-6% Carbon, scale 7/- per unit	,,	23	0	0
6-8% Carbon, scale 7/- per unit	,,	22	2	6
8-10% Carbon, scale 7/- per unit	,,	21	5	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 10/- per unit	,,	32	10	0
§Guar. max. 1% Carbon, scale 13/6 per unit	,,	34	17	6
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	38	17	6
‡Manganese Metal 96-98% Mn.	lb.	0	1	3
‡Metallic Chromium	,,	0	2	7
§Ferro-Vanadium 25-50%	,,	0	12	8
§Spiegel, 18-20%	ton	7	5	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	5	17	6
20/30% basis 25%, scale 3/- per unit	,,	7	15	0
45/50% basis 45%, scale 5/- per unit	,,	11	7	6
70/80% basis 75%, scale 7/- per unit	,,	18	0	0
90/95% basis 90%, scale 10/- per unit	,,	25	6	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	14	0	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
§Ferro Phosphorus, 20-25%	ton	15	0	0

FUELS.

Foundry Coke—						
S. Wales Export	—			—		
Sheffield Export	£0	15	6 to	£0	16	0
Durham Export	1	6	0 to	1	8	0
Furnace Coke—						
Sheffield Export	£0	15	6 to	£0	16	0
S. Wales ,,	—			—		
Durham	0	14	6 to	0	15	0

GUN METAL.

Commercial Ingots	£65	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb. 0	1	1
*Cored Bars	,, 0	1	3

LEAD.

Soft Foreign	£12	16	3
English	14	5	0

MANUFACTURED IRON.

Scotland—			
Crown Bars	£10	5	0
N.E. Coast—			
Rivets	11	10	0
Best Bars	11	5	0
Common Bars	10	15	0
Lancashire—			
Crown Bars	10	5	0
Hoops	13	0	0
Midlands—			
Crown Bars	10	7	6
Marked Bars	12	10	0
Unmarked Bars	—		
Nut and Bolt Bars	9	0	0
Gas Strip	10	17	6
S. Yorks.—			
Best Bars	11	0	0
Hoops	12	0	0

PHOSPHOR BRONZE.

*Bars, Tank brand, 1 in. dia. and upwards	lb.	1/1
*Cored Bars	,,	1/3
†Strip	,,	12¼
†Sheet to 10 W.G.	,,	12¾
†Wire	,,	1/0½
†Rods	,,	1/0¼
†Tubes	,,	1/5
†Castings	,,	1/1

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	15	0
Foundry No. 1	3	16	0
,, No. 3	3	13	6
N.E. Coast—			
Hematite No. 1	3	9	6
Foundry No. 1	3	1	0
,, No. 3	2	18	6
,, No. 4	2	17	6
Cleveland—			
Foundry No. 3	2	18	6
,, No. 4	2	17	6
Silicon Iron	2	1	0
Forge No. 4	2	17	0
N.W. Coast—			
Hematite	4	8	6
Midlands—			
N. Staffs Forge No. 4	3	6	0
,, Foundry No. 3	3	11	0
Northants—			
Forge No. 4	3	2	6
Foundry No. 3	3	7	6
Derbyshire Forge	3	6	0
,, Foundry No. 3	3	11	0
West Coast Hematite	4	6	6
East ,, ,,	4	2	6

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	£6 0 0 to £7 10 0
Bars, hammered, basis	£17 10 0 ,, £18 10 0
Blooms	£10 0 0 ,, £12 0 0
Keg steel	£32 0 0 ,, £33 0 0
Faggot steel	£20 0 0 ,, £24 0 0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£37	0	0
,, Braziery	34	0	0
,, Wire	—		
Brass	26	0	0
Gun Metal	35	0	0
Zinc	5	10	0
Aluminium Cuttings	50	0	0
Lead	11	0	0
Heavy Steel—			
S. Wales	2	7	6
Scotland	2	7	6
Cleveland	2	6	0
Cast Iron—			
Lancashire	2	5	0
S. Wales	2	7	6
Cleveland £2 8 0 to	2	11	0
Steel Turnings—			
Cleveland	1	12	6
Lancashire	1	0	0
Cast Iron Borings—			
Cleveland	1	8	6
Scotland	1	12	6

SPELTER.

G.O.B. Official	—		
Hard	£9	10	0
English	12	5	0
India	11	0	0
Re-melted	11	0	0

STEEL.

Ship, Bridge, and Tank Plates—			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	10	0	0
,, ,, (Marine) ,,	10	10	0
,, ,, (Land), N.E. Coast	10	0	0
,, ,, (Marine) ,,	10	10	0
Angles, Scotland	8	7	6
,, North-East Coast	8	7	6
,, Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails	8	17	6
Sheffield—			
Siemens Acid Billets	9	10	0
Hard Basic	9	12	6
Medium Basic	8	2	6
Soft Basic	6	5	0
Hoops	10	5	0
Manchester—			
Hoops	9	15	0
Scotland, Sheets 20 W.G.	9	10	0

HIGH SPEED TOOL STEEL.

Finished Bars 18% Tungsten. Extras	lb.	3/-
Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼ in. to ⅜ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ¾ in.	,,	3d.
,, ,, ¾ in. × ¼ in.	,,	1/-

TIN.

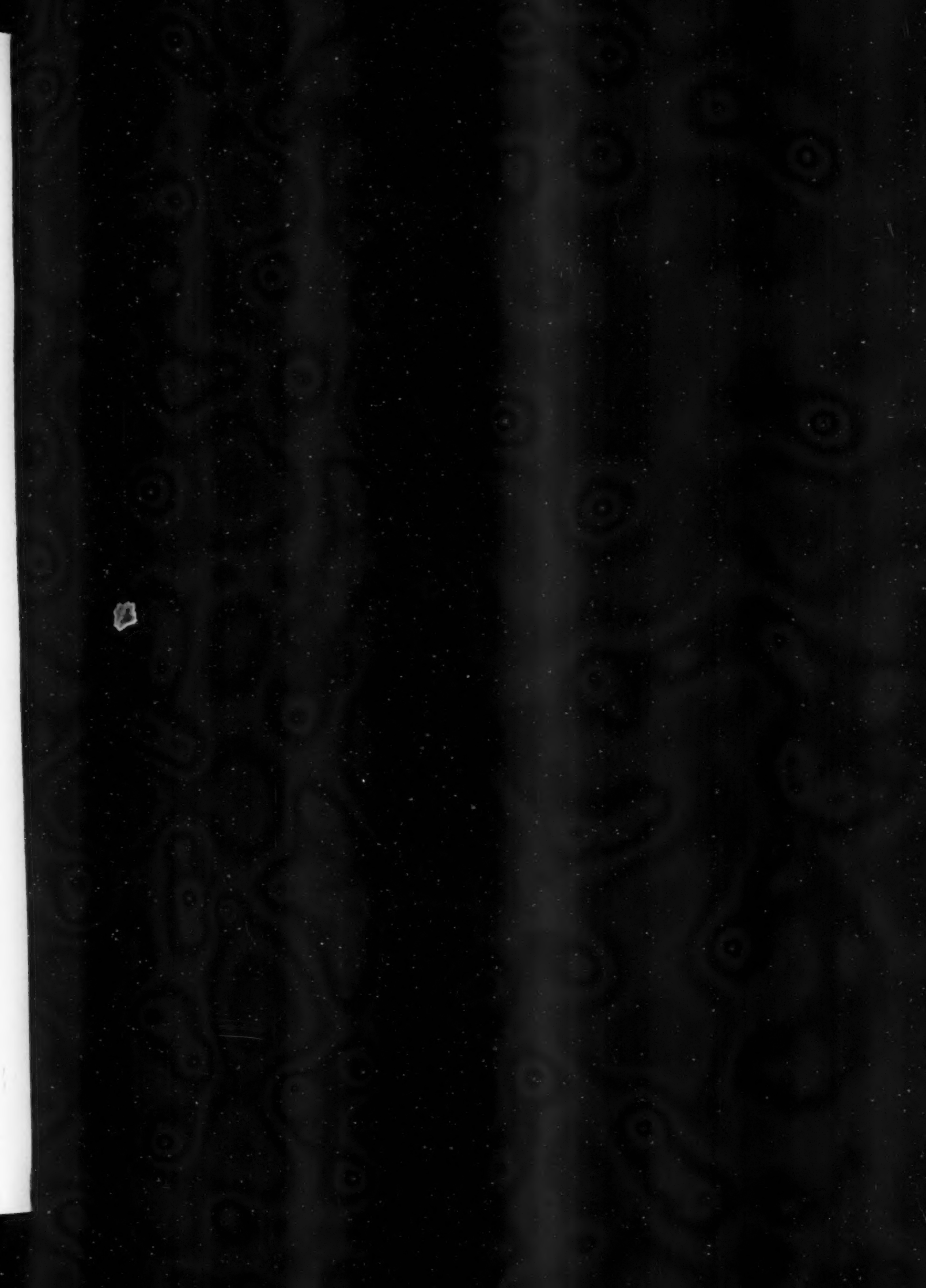
Standard Cash	£114	12	6
English	116	0	0
Australian	111	12	6
Eastern	114	5	0
Tin Plates I.C. 20 × 14	box	15/6	
Block Tin Cash	£118	10	0

ZINC.

English Sheets	£21	0	0
Rods	24	0	0
Battery Plates	16	13	0

* McKechnie Brothers, Ltd., quoted Feb. 7. † C. Clifford & Son, Ltd., quoted Feb. 7. ‡Murex Limited, quoted Feb. 9.

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Lancashire Steel Corporation's Current Basis Prices :—Wrought Iron Bars, £10 5s. 0d.; Mild Steel Bars, £7 2s. 6d.; Wrought Iron Hoops, £12; Best Special Steel Baling Hoops, £8 15s. 0d.; Soft Steel Hoops (Coopers' and Ordinary Qualities), £8 0s. 0d. to £8 5s. 0d; C. R. & C. A. Steel Hoops, £11 10s. 0d. to £12 0s. 0d; "Iris" Bars, £8 15s. 0d. All Nett Cash. Quoted Feb. 7.

§ Prices quoted Feb. 10, ex warehouse.